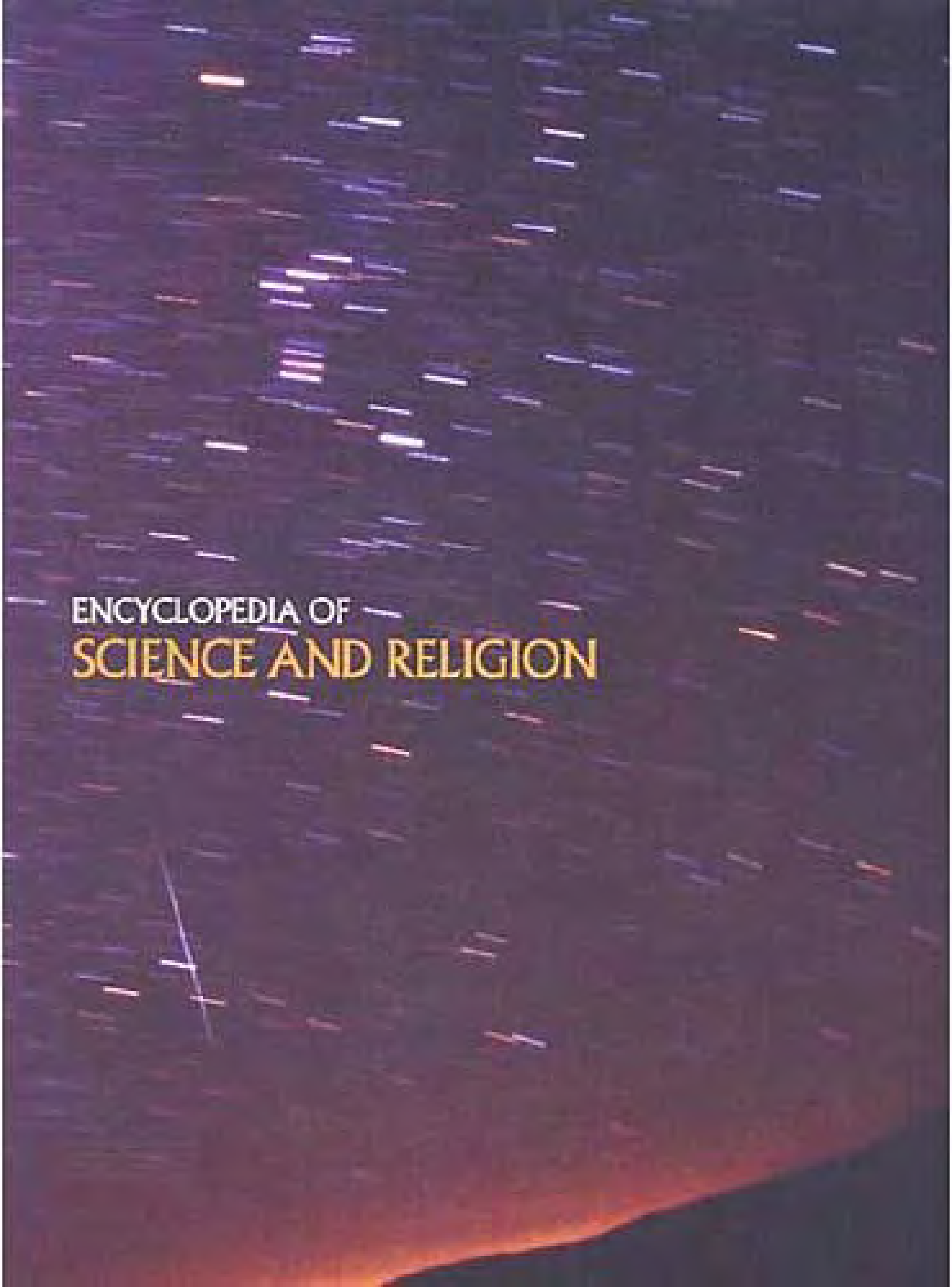

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Encyclopedia of Science and Religion

J. Wentzel Vrede van Huyssteen

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PREFACE

The dialogue between science and religion is one of the most prominent and visible discourses of our time. The complex but enduring relationship between the sciences and diverse world religions has now transformed itself into what some are calling a new scholarly field of *science and religion*. This multifaceted conversation has developed into a sustained and dynamic discourse with direct implications for contemporary culture. This discourse affects all religions, in both their intellectual and social dimensions. It also analyzes, supports, and constrains the global impact of the sciences of our times.

The *Encyclopedia of Science and Religion* reflects the breathtaking scope and pluralistic character of this ongoing dialogue. It is the most comprehensive work of its kind, and it is designed to be accessible to a wide readership from high school students to independent researchers and academics. Anyone fascinated by the ever-evolving impact of the sciences on religious belief in a global context will find the *Encyclopedia* a rich resource, for the historical relationship between science and religion certainly ranges from harmony and mutual support to stormy periods of intense conflict.

In the last two decades public awareness of and interest in this complex and often contentious relationship between science and religion has reached an unprecedented level. Courses in science and religion are now taught worldwide at a great number of educational institutions. Centers for the study of science and religion are actively pursuing the challenges and complexities of this dialogue; local and international societies for science and religion have been, and are being, established. There is also an exploding number of publications, journals, newsletters, and papers. Most recently, the science and religion dialogue has established an impressive new presence on the Internet.

All of these issues, interests, and constituencies are reflected in the *Encyclopedia of Science and Religion.* The challenging conversation between the sciences and religions is highlighted with entries focusing on issues that bear on topics such as behavioral studies and the human sciences; cognitive science and the neurosciences; computer science and information technology; physical sciences and cosmology; ecology; ethics and value theory; evolution; genetics; feminist and womanist issues; mathematics; methodology; medicine; philosophy; biology; paleontology and the anthropological sciences; and technology. World religions as varied as Bahá'í, Buddhism, Chinese religions, Christianity, Hinduism, Islam, Judaism, and Shinto are represented with individual entries or clusters of entries.

There are more than four hundred entries in the *Encyclopedia of Science and Religion,* all arranged in alphabetical order for easy reference. The entries range in length from several thousand words on broad topics, to a hundred words or so for key terms in the various sciences and religions. The editors see this work primarily as a reflection on the most important issues in the contemporary dialogue between the sciences and religions. A glance over the list of entries, however, indicates that the *Encyclopedia* also covers the critical history of the relationship between science and religion and offers historical biographies of a select number of important figures. All entries guide readers to further sources of information and exhaustive cross-references quickly and easily lead to related topics. The authority of the *Encyclopedia* is assured by the experts who have written the entries. The authors have written so as to make this *Encyclopedia* accessible for students in general, for the public at large, and for scholars in a variety of disciplines. In this way we have created a rich reference resource that is well suited to diverse library environments.

The frontmatter features a Synoptic Outline, covering the complete scope and every entry of the *Encyclopedia of Science and Religion.* The purpose of this Outline is to make the *Encyclopedia* even more accessible by grouping all entries into broad, topical categories. Teachers and readers are offered an organized map of the whole field of science and religion. In addition, a comprehensive Index provides readers with yet another means of access to the wealth of information contained in these two volumes, while an Annotated Bibliography of selected works introduces readers to those published works currently regarded as indispensable in the field of science and religion.

The editors would like to thank Ian Barbour, one of the most prominent scholars in the field, for graciously agreeing to act as a consultant at the initial planning phase of the *Encyclopedia of Science and Religion.* His advice was invaluable to us. We also thank the expert staff at Macmillan Reference USA for their outstanding support throughout this project. We extend our appreciation to the following persons at Macmillan: Elly Dickason, former publisher of Macmillan, for her initiative and encouragement at the beginning of this project; Michael McGandy, who was a pleasure to work with, and who guided us with unfailing professionalism and expertise; Hélène Potter, who oversaw the project with great vision, and was responsible in the end for pulling everything together; and Judy Culligan for all her hard work and a very professional level of copy editing. Here at the Princeton Theological Seminary my assistant Ryan Valentine did an outstanding job. He devoted a great deal of time developing the database that was critical to the beginning phase of this project and later assisted in the editing process. He was also responsible for preparing the Synoptic Outline and checking all cross-references. Taede Smedes did a first rate job of helping us put together the Annotated Bibliography.

The editors, finally, would like to express our deep gratitude to family members and loved ones who so consistently acknowledged and supported our work on this project.

J. WENTZEL VREDE VAN HUYSSTEEN

INTRODUCTION

The publication of the *Encyclopedia of Science and Religion* is a significant milestone marking the maturation of the contemporary dialogue between the sciences and religions. Not only does this *Encyclopedia* offer a massive amount of interdisciplinary and interreligious information, but it mirrors one of the most fascinating stories of our time: the emergence of an extensive international discussion among scientists of various specializations, philosophers of nearly all persuasions, and religious thinkers from all the major world religions. Spectacular advances in the sciences no longer easily threaten religions around the world because the risks and devastating consequences of new technologies have problematized the formerly unquestioned ideal of scientific progress. Scientific advances still challenge basic religious convictions, however, and the intellectual representatives of the world's religious traditions grapple with scientific knowledge more effectively and pervasively than ever before, thanks to the science-religion dialogue. Today sciences as varied as the neurosciences, ecology, and biotechnology raise questions about human beings and the future of our planetary home, perhaps especially for those who possess a sense of the divine. Similarly, chaos theory, quantum mechanics, and the ever-deepening understanding of the role of chance in biological systems conspire to challenge the notions of ultimate reality and divine action espoused by religious traditions and sacred texts.

At the same time, partly because of the unwanted side effects of science-driven technologies, there is a growing conviction that science in itself may never yield an ultimately satisfying explanation of human life and the world we inhabit. And yet the information about reality produced by the sciences is invaluable. Perhaps we have two domains of meaning here, with science and religion each ruler of its own domain. Or perhaps the structures and patterns of nature disclosed by the sciences connect with the more elusive yet existentially more immediate meaning typical of religious faith. Even as the religions of the world grow more accepting of the sciences, at least some intellectuals are noting how scientific methods and aims can enhance and perhaps support religious faith. Therefore, contrary to popular misconceptions, the relationship between the sciences and the various religions at the beginning of the twenty-first century is not about conflict or confrontation only. Those who participate actively in this dialogue are often deeply committed, not only to a specific science, but also to specific religious beliefs. Even scholars who are agnostic or atheistic are taking the interaction among sciences and the religions seriously because this relationship involves two of the dominant cultural forces of our time. Complicated and multilayered, the relationships among the various sciences and diverse world religions are not merely adversarial, nor simply a matter of neatly separable domains of discourse.

In the West the success and prestige of science has had a fundamental influence on the way that the voices of popular culture describe our world. As a result, relationships among the religions and the sciences have often suffered from what some intellectuals have called the modernist dilemma, where the objective and universally true claims of science are often unfairly contrasted with subjective and irrational religious beliefs. This has led to sharp distinctions between objective descriptions and subjective experiences, between scientific and symbolic uses of language, and between empirically justified scientific truths and privately held religious opinions. The appeal of such stark oppositions, however, has waned. *Scientism* is the term of approbation used for the attitude that takes for granted the alleged rational superiority of science and exclusive value of the scientific method for gaining knowledge. The reductionist views that define scientism are now being attacked relentlessly by scholars who point out that both scientific and religious beliefs, in spite of important differences, are historically and culturally embedded and shaped by comprehensive worldviews. The polarization between inappropriately reified and ahistorical notions of science and religion is collapsing and in its place is arising an appreciation for the integrity of diverse discourses and social activities, including those usually called the religions and the sciences. At least as importantly, scholars are attempting to uncover the profound rational and historical linkages that connect, as well as individuate, the religions and the sciences. These historical and philosophical exertions have shown not only that the great discoveries about the nature and history of the physical world have affected religious discourses in nearly all their manifestations, but also that the claims of the various world religions about our capacity to know, the ultimate meaning of the cosmos, and the place of human beings in an evolving universe often impact the way scientific inquiry is conducted.

In the contemporary discussion among the religions and the sciences, particularly as it has transpired in the West, the most influential attempt at representing the complex relationship between these two cultural forces has been Ian Barbour's fourfold typology. Barbour describes the different ways that the sciences have actually related and might possibly relate to the religions as *conflict, dialogue, independence,* and *integration*. Many subsequent models for relating religion and science have built on the legacy of this pioneering analysis. Even as contemporary factors from cultural pluralism to postmodern philosophy suggest other ways of relating the sciences to religion, Barbour's typology remains applicable and instructive. The literature today expresses an increasing awareness that the relations between science and religion can only be properly understood if the specific cultural, historical, and intellectual contexts have been taken into account. The vast amount of information collected in this *Encyclopedia of Science and Religion* illustrates the richness and complexity of this interpretative task.

The growing conversation between science and religion that emerged with new vigor in the late twentieth century has a number of striking features. First, though once considered an esoteric field, the study of the relationship between science and religion is no longer a highly specialized discourse, open only to the few intellectuals who are privy to the complexity of the issues involved. The science and religion debate has become a public affair. The active presence of the debate on the Internet, as well as an explosion of published newsletters, papers, books, and conferences, further enhances this high public profile. Second, whereas there are new debates and ideas within science and religion, in many ways the dialogue extends familiar and longstanding debates known by different names: "faith and reason" or "faith and culture" (in the West) and "*pramana* theory" (in South Asian debates on valid sources of knowledge). Third, not only is the science and religion conversation alive and well in many cultures all over the world but, as this *Encyclopedia* clearly shows, a number of academic centers and scholarly associations now concentrate their considerable intellectual and financial resources on issues at the interface of science and religion. The discussion among the sciences and the religions has also found a permanent place in schools, colleges, seminaries, and universities. Courses in religion and science are now taught on all academic levels throughout the world, complemented by a number of high-profile endowed chairs in the field. Finally, one of the most important milestones in this ever-growing field was the founding of the *International Society of Science and Religion* in August 2002 in Granada, Spain.

The *Encyclopedia of Science and Religion* is directed mainly at students and their teachers. They will find all of the most important issues in this field addressed in an accessible and inclusive manner. Outstanding experts from around the world have contributed to the *Encyclopedia*. The comprehensive list of entries focuses on the principal sciences and the major scientific discoveries of our time and on all the challenging and controversial topics that have emerged from this context and have affected the world religions in different ways. Both historical and contemporary issues in science and religion are treated under the headings of the major world religions. The religions represented here include Buddhism, Bahá'í, Chinese religions (Confucianism and Daoism), Christianity (Anglican, Evangelical, Lutheran, Orthodox, Pentecostalism, Radical Reformed, Reformed, Roman Catholic), Hinduism, Islam, Judaism, and Shinto. The various sciences represented in the entries of this *Encyclopedia* cover a wide spectrum of disciplines, such as behavioral studies and the human sciences; cognitive science and neuroscience; computer science and information technology; cosmology; ecology; evolutionary sciences; genetics; primatology; mathematics; medicine; the physical sciences (including chemistry and physics); and the life sciences (including biology, paleontology, and the anthropological sciences). There is also a series of entries on relevant disciplines within the humanities, including ethics and value theory; feminism; philosophy (including methodology, epistemology, philosophy of science, philosophy of religion); theology and religious thought; and technology.

There are interesting, if controversial, reasons why Christian theologians have often taken the lead in discussing the relationship of the sciences to the religions. An unfortunate side effect of this leadership is that, at certain times and places in recent decades, the dialogue has seemed limited by the caricature that only Christianity fostered modern science. But this version of events is historically inaccurate and deeply misleading. The evidence is that all religious traditions and all forms of scientific work have something to gain as well as lose in the process of mutual interaction, and the historical record demonstrates profound and longstanding engagement between science and religion in all literate cultures. Selecting entries and authors to express this guiding conviction and to represent the truly global character of the dialogue has been one of the main goals of this *Encyclopedia*.

The *Encyclopedia of Science and Religion* highlights for our readers the dynamic and ongoing discussion among the religions and the sciences, and demonstrates that it is both possible and fruitful to bring together the spectacular success of science and the wisdom of religion in a constructive interchange. In doing this, the difficult but exciting interdisciplinary conversation between science and religion moves forward to a more challenging phase of interreligious dialogue where religions could be in conversation with each other through their relationship to the sciences. This may go beyond regular interfaith dialogue. If this can be achieved successfully, the multileveled and comprehensive scope of this work will serve well the future of the science and religion interchange.

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Feminisms and Science

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Contextualism
Fallibilism
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Worldview

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Age of the Universe
Eschatology
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Thermodynamics, Second Law of

JEROME A. STONE
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Empiricism

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Sociology

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University of Durham, St. John's College
Christianity, Anglican, Issues in Science and Religion

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Dualism
Soul
Special Providence

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Evolution, Human
Missing Link
Paleoanthropology
Paleontology

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Evolutionary Psychology
Neural Darwinism
Spirit

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Liberation

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Autopoiesis
Constructivism

HAVA TIROSH-SAMUELSON
Arizona State University
Judaism

THOMAS F. TRACY
Bates College
Divine Action
Double Agency
Providence
Special Divine Action

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Positivism, Logical
Realism

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Models

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Space and Time

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Self

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University of Groningen
Eternity
Omnipotence
Omnipresence
Omniscience

JITSE M. VAN DER MEER
Redeemer University
Metaphysics
Order

PETER VAN NESS
Yale University School of Medicine
Spirituality and the Practice of Science

HOWARD J. VAN TILL
Calvin College
Clockwork Universe
Creation Science
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University of Manchester
Postmodernism
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KEITH WARD
Oxford University
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John Templeton Foundation
Anthropology
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Culture, Origins of

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Gene Therapy
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Genetic Testing

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Abortion

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Prayer and Meditation
Psychology
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Scopes Trial

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Graduate Theological Union, Berkeley
Science and Religion

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Mendel, Gregor

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Modernity

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Calvinism
Christianity, Reformed, Issues in Science and Religion

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Boston University
Spirituality

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Big Bang Theory
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ADRIAN M. WYARD
Counterbalance Foundation
Science and Religion in Public Communication

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China Graduate School of Theology
Chinese Religions and Science
Chinese Religions, Confucianism and Science in China
Chinese Religions, History of Science and Religion in China

AMOS YONG
Bethel College
Christianity, Pentacostalism, Issues in Science and Religion

LAURIE ZOLOTH
San Francisco State University
Judaism, Contemporary Issues in Science and Religion

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A

ABORTION

Abortion is the termination of a pregnancy before the time of extrauterine viability. An abortion terminates the life of the embryo (the fertilized egg before three months of growth) or the fetus (after three months). *Spontaneous abortions,* also called *miscarriages,* occur when the fetus or embryo is spontaneously expelled by the body. An *induced abortion* occurs when there is deliberate human intervention to end the pregnancy. Induced abortions can be accomplished medically or surgically.

Medically induced abortions are accomplished by giving drugs like mifepristone (RU-486), which block the work of the hormone progesterone and soften the lining of the uterus, thus ending the pregnancy. Medically induced abortions can generally only be used if the woman is less than seven weeks from her last menstrual period. Mifepristone is administered in conjunction with another medicine called misoprostol, which causes the uterus to cramp and expel the embryo.

Within the first trimester of pregnancy, the most common form of surgical abortion is *vacuum aspiration*. During the second trimester, *dilation* and *evacuation* procedures (D & E) are performed. Finally, stimulating contractions that expel the fetus from the uterus can also induce abortion.

Ethical issues

Abortion raises significant scientific, legal, religious, and ethical issues: the understanding of life and death, the definition of a human person, the rights of the mother and the fetus, and the impact of new scientific discoveries on reproduction. Certain scientific and technological discoveries, including stem cell research, cloning, and artificial reproduction, have complicated the abortion issue. The status of the fetus is probably the most controversial issue: Is the fetus a person with the same rights as those who are born? Some argue that the embryo from the moment of conception has the same rights as a person *extra utero*. Others argue that the early embryo is human life but not a human person. The political state also has an interest both in the autonomy of the mother and the health of the baby. Sometimes, the autonomy of the mother can be in tension with her maternal responsibility to the fetus.

With the increased use of fertility drugs and assisted reproductive technologies, many patients can conceive who were unable to conceive in the past. Some of these technologies may result in high order multiple pregnancies (with four or more fetuses), which have a substantial risk of the loss of all fetuses before the period of extra-uterine viability (twenty-two to twenty-four weeks gestation). The parents' options include carrying all of the fetuses until birth, eliminating all of them, or selectively terminating some fetuses. Selective reduction may enhance the chance of survival of some fetuses in a high order multiple pregnancy.

Discovery, diagnosis, prevention, and therapy of certain genetic or medical diseases complicate decisions surrounding abortion. Parents can now determine when the fetus is in-utero whether it carries possible genetic predispositions to diseases like cystic fibrosis, Huntington's chorea, early Alzheimer's, and sickle cell anemia. Prenatal testing also allows detection of chromosomal abnormalities, such as Down syndrome. Ultrasound, now widely used during pregnancy, can document a wide variety of birth defects. Although some of these problems may be treatable in-utero, in most cases no therapy is available, and the parents must decide whether to continue the pregnancy. In addition, some maternal medical conditions, such as pulmonary hypertension, may pose a significant threat to the mother's life if pregnancy continues.

Physicians, parents, and insurance companies face difficult decisions about abortion. The human and economic costs of caring for children with medical or genetic disorders can be great. Opponents of abortions that are performed to address these problems raise the concern that the weak and vulnerable in society will have no rights. There is potential for discrimination based on genetic information.

Religious views

Religious views on abortion are pluriform, ranging from those who consider abortion as murder to those who justify it as a necessary means to an end. The spectrum of diversity can be found not only among world religious traditions, but also within religious traditions. The discussion focuses primarily on the status and rights of the fetus, the status and rights of the mother, the role of medical technology, the value of life (quantity and quality), the political and socioeconomic concerns surrounding fertility and infertility, and the nature of what it means to make difficult ethical decisions in a community of faith.

Judaism, Islam, and Christianity are related monotheistic religions that use religious texts, human reason, and teaching authorities for making ethical decisions. Within and among these three traditions, there are deep and potentially divisive views on abortion. For example, some religious scholars believe that God creates all life. According to this view, the embryo is a human person endowed with rights from the moment of conception. To reject this life is to reject the creation of God. Abortion is considered a sin against life along with murder, genocide, and self-destruction, and any destruction of an embryo would be considered sin, even when done in response to prenatal diagnosis of genetic disease.

In contrast, some scholars of religion, including Daniel Maguire, explain that abortion may be permissible for many reasons. Maguire points out in *Sacred Choices* (2001) that there is only one direct reference in scripture to accidental abortion—Exodus 21:22, which states that someone who injures a woman and causes her to miscarry must pay a fine paid to her husband. If the woman dies from her injuries, however, the punishment for the person who injured her is death. Clearly, in this text, the fetus is not considered a person with the same status as the woman, and abortion would be permitted for some reasons, such as preventing extreme fetal abnormalities and saving the life of the mother.

Judaism. Some Jewish scholars, such as Laurie Zoloth, connect reproduction to justice. Judaism takes into account the good of the entire community in making decisions about abortion. This approach derives from Judaism's root commitment that every human being is a child of God, born in the image of God. Reproduction is undertaken not merely for its own sake, but for the sake of the community. Abortion is thus permitted for the woman to avoid disgrace or for health reasons of both mother and fetus. In some Jewish traditions, the first forty days of conception are considered like "water" and the fetus does not have an ontological status of a person.

Islam. The approach from Islam concerning abortion and contraception has generally been one that considers the common good of the community. Muslims see themselves as vice regents of God, called to do God's work in this world. Islam's ethical practices are flexible and are often adapted to political and social climates. As Gamal Serour points out in *The Future of Human Reproduction* (1998), for Muslims abortion can be "carried out to protect the mother's health or life or to prevent the birth of a seriously handicapped child" (p. 196).

Christianity. Within the Christian tradition, perspectives on abortion vary dramatically. For example, within Roman Catholicism different scholars draw different conclusions about permitting abortion. Many consider the official Catholic position on abortion to derive from the 1930 encyclical *Casti Connubii* (On Christian Marriage) of Pope Pius XI and the 1987 *Donum Vitae* (Gift of Life) of Pope John Paul II. On the issue of genetic screening for selective abortion, *Donum Vitae* states that "a woman would be committing a gravely illicit act if she were to request such a diagnosis with the deliberate intention of having an abortion should the results confirm the existence of a malformation or abnormality." Furthermore, humans cannot assume the role of God when using embryos in research from IVF (in vitro fertilization). *Donum Vitae* states that the researcher "sets himself up as the master of the destiny of others inasmuch as he arbitrarily chooses whom he will allow to live and whom he will send to death and kills defenseless human beings." However, Maguire and others have pointed out that papal statements on abortion are not considered infallible and explain that abortion would be permitted for some reasons.

Protestant denominations vary on their stance on abortion. Within Protestantism, decisions about abortion are not made by a central teaching magisterium but within a community of shared discernment. Denominations such as the Evangelical Lutheran Church in American and the United Church of Christ do not take an official stand on the status of the fetus. Both the fetus and the mother are taken into account when confronting decisions concerning abortion. Other Protestant teachings are more consistent with Roman Catholicism and consider abortion a sin. In some cases, exceptions are made for the life of the mother.

Asian religions. According to Maguire, Asian religions like Daoism and Confucianism have understood abortion as a necessity in some cases and have extended compassion to those involved. These nontheistic religions emphasize the family and community as the primary social unit, and decisions about abortion are made within this social context. Buddhism considers all life as linked and interdependent, and most Buddhists believe in reincarnation and understand that life begins at conception. These beliefs could preclude abortion at any stage, but many Buddhists permit abortion, particularly for the sake of the mother. Intention is central to Buddhist morality and so the action of abortion must also include the intentions of the moral actors.

See also BUDDHISM; CHINESE RELIGIONS, CONFUCIANISM AND SCIENCE IN CHINA; CHINESE RELIGIONS, DAOISM AND SCIENCE IN CHINA; CHRISTIANITY, LUTHERAN, ISSUES IN SCIENCE AND RELIGION; CHRISTIANITY, ROMAN CATHOLIC, ISSUES IN SCIENCE AND RELIGION; CLONING; DAO; GENETIC TESTING; HUMAN GENOME PROJECT; ISLAM, CONTEMPORARY ISSUES IN SCIENCE AND RELIGION; JUDAISM, CONTEMPORARY ISSUES IN SCIENCE AND RELIGION; REPRODUCTIVE TECHNOLOGY; STEM CELL RESEARCH

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ADAPTATION

The term *adaptation* refers to changes in an organism's structure, function, or behavior that increase its ability to live in a particular environment. As such, adaptation is a central term in the life sciences. The many known examples of animals and plants adapting to their environment were the basis for the theories of evolution formulated by Charles Darwin (1809–1882) and Jean–Baptiste de Lamarck (1744–1829). Adaptation in the Darwinian sense describes a process of evolutionary change by natural selection. In this process the average performance of the individuals in a population with respect to survival and reproduction is improved.

The term adaptation is also used to describe the result of the process of evolutionary change (the state of being adapted) or to describe the "solution" to a problem that is set by the environment. The word is used this way in the *adaptationist program,* which has been criticized for explaining traits post hoc as having evolved to serve certain functions. Because the environment of any organism is continuously changing, the degree of adaptation is never optimal, and adaptation is, therefore, a never-ending process.

Not all traits in an organism or features of an organism's appearance are necessarily the result of adaptation; they may be by-products of selection acting on other traits. For example, the increased brain size in humans is considered to be a side effect of selection favoring increased body size. Specific traits can also be the result of adaptations for other functions that have since changed. For example, feathers in birds originally evolved to provide insulation, and only later were they used for flying. Physiological adaptations are plastic responses to the physical environment that occur within a lifetime and are not inherited by the next generation. Such adaptations can be of short duration and reversible, such as the adaptation of the eye to light and dark, or they may be long-lasting, such as the increased number of red blood cells in humans who live at high altitudes.

See also EVOLUTION; FITNESS; LIFE SCIENCES; SELECTION, LEVELS OF

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AESTHETICS

Aesthetics is the aspect of axiology that deals with the intrinsic value found in people's immediate sense experiences or their responses to sense experiences: judging them ugly, beautiful, or sublime. Aesthetics, which focuses on the uniquely particular, contrasts with science, which focuses on the general laws those particulars illustrate. Aesthetic theories can be about experiences of natural objects and events, but are usually concerned with art works and artistic creations. Aesthetic judgments are usually said to be disinterested, an enjoyment of the unique content of an immediate experience for its own sake. Marxists, postmodernists, and feminist theorists disagree, however, claiming that all such judgments are expressions of an interest.

See also AXIOLOGY; BEAUTY; VALUE; VALUE, SCIENTIFIC

GEORGE ALLAN

AFTERLIFE

See LIFE AFTER DEATH

AGE OF THE UNIVERSE

In contemporary scientific cosmology, the age of the universe is the time that has elapsed since the Big Bang, which in standard cosmological models is the past limit to the hotter, denser phases that are encountered as one goes farther and farther back into the past. In these models the Big Bang is a singularity, a region characterized by infinite density, temperature, and curvature. Quantum gravitational and quantum cosmological treatments of the

Big Bang, using concepts like superstrings, are beginning to provide a more adequate description of this primordial cosmological epoch, which is often referred to as the Planck era, during which the temperature of the universe was above 10^{32} K (kelvin). Here, classical relativistic gravitational theory (Albert Einstein's General Relativity) breaks down. It is from this extremely hot Planck era that the universe emerges with its three spatial dimensions, its one time dimension, its four basic physical interactions, and its matter and radiation. Before that emergence they were all unified in ways that are not yet completely understood.

A rough upper limit on the age of the universe, t_H, is given by the reciprocal of the Hubble parameter now, H_0, which gives the rate of expansion of the universe per unit distance. Thus, $t_H = 1/H_0$. Using the currently measured range of values of H_0, t_H is between twelve to sixteen billion years. Compare this to the very reliable age of the Earth and the sun, which is about 4.8 billion years. These ages have been confirmed by a variety of astronomical and isotopic techniques, including the measurement of the ages of stars in globular clusters (which are very old), and the estimation of how much uranium has decayed to lead and how much rubidium has decayed to strontium.

From the point of view of prescientific cultural and religious traditions, the age of the universe is the time that has elapsed since the world or the universe was created. In many traditions the creation is also taken to be the "event" in which time itself began. Some of those who interpret the Genesis creation and pre-Abraham historical accounts literally—as scientifically and historically reliable documents describing the formation of the universe and of the world, and earliest human history—have calculated the age of the world and of created reality (the universe) to be about 6,000 years, having begun in 4004 B.C.E. This has been done by counting the generations listed in Genesis from Adam and Eve to Abraham, and then estimating the number of years from Abraham to Moses, both of which are fairly well known, to the present. Experts have disputed this literal approach, of course, particularly because it is strongly contradicted by independent bodies of evidence from both the natural and the human sciences. It also fails to recognize the mythological and legendary character of the relevant Genesis sources. This does not mean that the Genesis sources are not revealing and expressive of important truths, but it does mean that those truths are neither scientific nor directly historical, but rather religious and theological truths.

The cosmological age of the universe since the Big Bang, although it certainly has important theological significance, cannot be interpreted as the time since the creation of the universe, if *universe* is understood to mean all that exists and not God. There could have been and there could be many other regions of reality, either completely separate from or linked with ours only at the Big Bang itself, which preceded or are older than our observable universe. Furthermore, it is unclear whether "creation" or "the first moment of creation" took place at any definite time. However, it does make some sense to date the beginning of the observable universe at the Big Bang, even though the coordinated manifold of primordial quantum events is not adequately understood.

See also BIG BANG THEORY; COSMOLOGY, PHYSICAL ASPECTS; SINGULARITY; STRING THEORY

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AGGRESSION

Aggression is behavior or a behavioral urge with the object of threatening or harming primarily members of one's own species. Several theories attempt to explain aggression.

Theories of aggression

The theory of instinct in ethology, as proposed by Konrad Lorenz (1903–1989), supposes that humans, like other biological creatures, are so constituted that they either continuously or periodically produce physiological energies that must seek outlet in certain kinds of species-specific aggressive behavior. Other ethologists argue that although innate genetic codes, as well as neural and hormonal processes, account for an aggressive disposition, there is no reason to assume the existence of aggressive energies. All ethologists agree, however, that aggression has arisen in the course of evolution and serves the same basic functions in animals and humans in regulating the intercourse between members of a species, although the regulation involves more psychological and cultural aspects with humans than with other animals.

This assumption is endorsed by sociobiology, first systematized by Edward O. Wilson (1929–), which studies the social behavior of humans using evolutionary methods. Like ethologists, sociobiologists presume an innate aggressive disposition in humans, but sociobiologists define innateness as the measurable *probability* that aggressiveness will develop in a species within a specified set of environments, not the *certainty* that it will develop in all kinds of environments.

The psychoanalytic drive theory of Sigmund Freud (1856–1939) resembles the instinct theory of Lorenz in the assumption that innate drives represent physiological energies. Freud departs from Lorenz, however, by assuming that the activity of the drives does not result in species-specific behavior patterns. Freud concluded that two drive complexes embodied in human beings constitute the basic sources of all human behavior; these were the life-building *Eros* and the life-demolishing *Thanatos,* with aggression, directed both outwards against others and inwards against oneself, as its central feature.

The theory of needs by Henry Murray (1893–1988) put forward a list of about twenty presumably universal human needs, among them aggression. In need theory there is no place for physiological energies. If a certain need, such as aggression, is dominant within a person in many different situations, it also appears as a personality trait.

The frustration theory, first presented by John Dollard (1900–1980) and his colleagues, explains aggression in a different way. Although aggression probably is a universal human disposition, aggressive behavior arises only as a reaction to incidents where purposeful behavior is blocked. Because this theory can only explain some kinds of aggression, it was modified by Leonard Berkowitz (1926–), who argued that aggression might still be a basic reaction to frustration.

The theory of learning proposed by Albert Bandura (1925–) and others places the origin of aggression solely in the social environment in assuming that aggressive behavior is learned during life history. Aggression is learned either because it is rewarded, or at least not sanctioned, and thereby reinforced. It may also be learned by observing aggressive behavior at home, on the streets, or from the media and entertainment industries, which show that aggression is worthwhile because it gets results, with aggressive people becoming models for imitation.

There might be elements of truth in all the theories, depending on which kind of aggression is in question in which kind of context: physical or mental, intended or reactive, instrumental or spontaneous, hostile or teasing, assaulting or defending, directed toward others or toward oneself, status demonstration, group conflict, sex, age, personality, and so on. Innumerable circumstances may influence the causes of aggression and aggressive behavior may involve a wide spectrum of explanations.

Aggression as evil

Anger is a faithful partner to aggression. For medieval Christians wrath was one of the seven deadly sins. Only God could pass judgment on righteous and unrighteous deeds, and in many cases anger arises when an offense is experienced as unjust. This tenet might have left deeper marks on culture than people are aware of, showing up in the widespread condemnation of anger and aggression. While moderate anger can instigate constructive action, blind anger often leads to destructive aggression. Yet to psychology and biology even furious anger and aggression cannot in itself be sinful, let alone evil. Because aggression is probably an unavoidable human trait, be it conceived of as innate or acquired, from a scientific point of view the very occurrence of aggression cannot be malice, and the absence of aggression cannot be kindness. For conceptions of good and evil to make scientific sense, evil must be viewed as the absence of an attempt to control aggression, thus preventing love to prevail.

In the animal kingdom human beings alone are able to curb their natural impulses and their learned habits, at least to some extent, and to listen to the voice of conscience, moral qualities that can be learned and even taught using psychological techniques. The attempt to curb aggressive behavior might not succeed, which in itself is not evil because it is bound to happen now and then. Evil is only the absence of the attempt to curb aggression, and the absence of remorse at not doing so. In psychological terms, such remorse could be called guilt in a more general sense than the concrete failure of the attempt, due to the conscience, which in its innermost voice tells a person that every concrete failure is a sin against the general good or a sin against love understood as the basic source of bonding and attachment in personal and social life. In this way, the concrete failure to curb aggression makes a person guilty against humankind, not only against the victim of the concrete failure. If a person grasps this idea of aggressive behavior, and yet in defiance and pride does not attempt to control aggression or seek atonement for the sin of failing to control it, then this person might be called evil. If so, probably all people are evil now and then, and many are evil fairly often. However, control can take the shape of inhibition and aggression can be turned inwards, which is not always mentally healthy either.

See also ALTRUISM; EVIL AND SUFFERING; PSYCHOLOGY; SOCIOBIOLOGY

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ALGORITHM

An algorithm is any well-defined procedure for solving a given class of problems. Ideally, when applied to a particular problem in that class, the algorithm would yield a full solution. Nonetheless, it makes sense to speak of algorithms that yield only partial solutions or yield solutions only some of the time. Such algorithms are sometimes called "rules of thumb" or "heuristics."

Algorithms have been around throughout recorded history. The ancient Hindus, Greeks, Babylonians, and Chinese all had algorithms for doing arithmetic computations. The actual term *algorithm* derives from ninth-century Arabic and incorporates the Greek word for number (*arithmos*).

Algorithms are typically constructed on a case-by-case basis, being adapted to the problem at hand. Nonetheless, the possibility of a universal algorithm that could in principle resolve all problems has been a recurrent theme over the last millennium. Spanish theologian Raymond Lully (c. 1232–1315), in his *Ars Magna,* proposed to reduce all rational discussion to mechanical manipulations of symbolic notation and combinatorial diagrams. German philosopher Gottfried Wilhelm Leibniz (1646–1716) argued that Lully's project was overreaching but had merit when conceived more narrowly.

The idea of a universal algorithm did not take hold, however, until technology had advanced sufficiently to mechanize it. The Cambridge mathematician Charles Babbage (1791–1871) conceived and designed the first machine that could in principle resolve all well-defined arithmetic problems. Nevertheless, he was unable to build a working prototype. Over a century later another Cambridge mathematician, Alan Turing (1912–1954), laid the theoretical foundations for effectively implementing a universal algorithm.

Turing proposed a very simple conceptual device involving a tape with a movable reader that could mark and erase letters on the tape. Turing showed that all algorithms could be mapped onto the tape (as data) and then run by a universal algorithm already inscribed on the tape. This machine, known as a universal Turing machine, became the basis for the modern theory of computation (known as recursion theory) and inspired the modern digital computer.

Turing's universal algorithm fell short of Lully's vision of an algorithm that could resolve all problems. Turing's universal algorithm is not so much a universal problem solver as an empty box capable of housing and implementing the algorithms placed into it. Thus Turing invited into the theory of computing the very Cartesian distinction between hardware and software. Hardware is the mechanical device (i.e., the empty box) that houses and implements software (i.e., the algorithms) running on it.

Turing himself was fascinated with how the distinction between software and hardware illuminated immortality and the soul. Identifying personal identity with computer software ensured that humans were immortal, since even though hardware could be destroyed, software resided in a realm of mathematical abstraction and was thus immune to destruction.

It is a deep and much disputed question whether the essence of what constitutes the human person is at base computational and therefore an emergent property of algorithms, or whether it fundamentally transcends the capacity of algorithms.

See also COMPLEXITY

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ALGORITHMIC COMPLEXITY

Algorithmic complexity measures the computational resources needed to solve computational problems. Computational resources are measured in terms of either time (i.e., number of elementary computational steps per second) or space (i.e., size of memory, usually measured in bits or bytes) or some combination of the two. If computational devices had unlimited memory and could perform calculations instantaneously, algorithmic complexity would not be an issue. All real-world computers, however, have limited memory and perform calculations at fixed rates. The more time and space required to run an algorithm, the greater its algorithmic complexity.

See also COMPLEXITY

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ALTRUISM

Altruism is a modern concept attributed to Auguste Comte, a French philosopher who founded the field of sociology in the mid-nineteenth century. The idea of altruism has antecedents in the early modern discussion of benevolence and in such ancient religious notions as Buddhist compassion and Christian *agape.* An important difference is the explicit focus in altruism on the other as the object of concern, which, in turn, reflects the sharper focus on the self that is characteristic of modern self-consciousness. For Comte, altruism identified the concern for others that he expected would characterize the positive religion of humanity that was destined to replace the false religion of the prescientific, theological, and metaphysical eras. Although Comte would have been disappointed with the extent to which altruism has actually flourished, his concept has become an enduring, if ambiguous, staple of modern Western understanding.

Altruism in biology and sociobiology

The notion of altruism has been accorded a significant role in biology, and especially in the refinements of sociobiology, where the term has a technical meaning that narrows the conventional sense of concern for others in terms of the biological concentration on reproduction. As, from a biological perspective, the point of life is reproduction, altruism acquires the meaning of actions that diminish the reproductive prospects of the altruist, while enhancing those of the recipient of the action. For biology and sociobiology, altruism represents something of an anomaly. Because evolution favors the development of inclusive fitness, altruism should have been selected out of existence. But it is firmly present, in the strictest biological sense, in whole classes of nonreproductive workers like ants and bees. Sociobiology has resolved this anomaly by defining altruism out of existence. What may look like altruism on the behavioral level may turn out to be decidedly selfish on the gene level if the recipient of the altruistic behavior is a relative of the putative altruist and so shares the same genes. The concept of *kin altruism* thus explains the sacrifice of reproductive prospects for those who share the same genes. Cases where the beneficiary has no identifiable relation are covered by the notion of *reciprocal altruism*. Here again, what appears to be altruistic behavior is really selfish because it is done with the expectation, genetically speaking, of reciprocal aid that may be required by the altruist in the future. The imperialism of selfish genes thus destroys any semblance of altruistic behavior at the biological level.

Altruism in social science and ethics

The assumption of the primacy of self-interest that dominates sociobiology has been questioned in the social sciences with research into altruism and helping behavior, and yet here too the self-interest assumption remains strong. The favored alternative to a self-interest reading involves a calculative or caring mutuality, for which expectations of altruism may be more detrimental than self-interest. Altruism represents a morality of service and self-sacrifice. Critics point out that such a noble and self-deprecating approach has often been expected of other people; even when its advocates have taken it seriously themselves, it can constitute an individualistic heroism that deflects attention and action from the real possibilities of mutuality inherent in the actual social relations in which people find themselves. Approaches as diverse as the justice procedures of John Rawls (which challenge one to imagine one is designing a society in which one does not know where one will be placed so that one will have to take into account the state of those on the lowest rungs of the social and economic ladders because one might be one of those people) and the alternative stance of feminist care morality (which sees a focus on individual moral action, even, and perhaps especially, the most heroic, as misguided neglect of the social relations of give and take that daily lives actually involve) agree on the superiority of social mutuality over allowance for, much less expectations of, altruism.

Limitations of the concept

Altruism does carry the liabilities of its origins. As a social concept, meant to counterbalance the excesses of self-interest, altruism is finally only intelligible in relation to the self-interest with which it is contrasted; it is concern for others, rather than what is taken to be the natural and virtually inevitable concern for self. Because it carries this legacy, altruism bears the liability of undermining itself through its own deliberateness. Deliberate focus on the other as the object of one's concern may represent an implicit interest in the self as the source of this concern—a consideration that prompted the nineteenth-century American writer Henry David Thoreau to allow that he would run for his life if he knew that someone was coming to see him with the deliberate intention of doing him good. It is this lack of attention and openness to the other that bothers many contemporary critics of the loss of mutuality in the focus on altruism. That such dangers warrant a dismissal of the whole notion, however, is another matter. Without the moral heroism that altruism entails, reliance on the mutuality of social relations may amount to a frightening leveling down of moral expectations and results. The saints, the philosopher William James contended, are the impregnators of culture, raising it to higher levels through their risking ways of living that hold no obvious benefit for themselves. The philosopher and ethicist Edith Wyschogrod has nominated altruists as the saints of secular culture.

Religious altruism

Suspicion of altruism may be a reflection of the secularization of contemporary culture, and the concept itself may be indicative of a lingering religious sensibility in Comte, who still expected a religion of humanity to develop. As such, it suggests that concern for others is finally only feasible through the deliverance from self that is offered by and celebrated in religion. This allows for the indirection that makes the aims of altruism possible, without the short-circuiting of a focus on altruism itself, and hence on the altruist. Of course, this in no way entails that devotees of religion exemplify the reality to which altruism points. Fortunately, religion also offers forgiveness along with the altruistic vision. This could represent the counsel of complacency that advocates of mutuality fear, but it could also represent the heroic initiative and extravagant saintliness that the realism of social mutuality threatens to undermine.

See also ANTHROPOLOGY; BEHAVIORISM; CHRISTIANITY; EVOLUTION; SELF; SELFISH GENE; SOCIOBIOLOGY

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ANABAPTIST

See CHRISTIANITY, RADICAL REFORMED, ISSUES IN SCIENCE AND RELIGION

ANGLICANISM

See CHRISTIANITY, ANGLICANISM, ISSUES IN SCIENCE AND RELIGION

ANIMAL RIGHTS

The modern animal rights movement, which originated in the 1970s, may be understood as a reaction to dominant emphases within science and religion (principally, though not exclusively, Christianity). When the Jesuit Joseph Rickaby wrote in 1888 that "Brute beasts, not having understanding and therefore not being persons, cannot have any rights" and that we have "no duties of charity or duties of any kind to the lower animals as neither to stocks and stones" (*Moral Philosophy,* vol. II, pp. 248–9), he was only articulating, albeit in an extreme form, the moral insensitivity that has characterized the Western view of animals.

That insensitivity is the result of an amalgam of influences. The first, and for many years the most dominant, was the "other worldly" or "world denying" tendency in Christianity, which has, at its worst, denigrated the value of earthly things in comparison with things spiritual. Traditional Catholicism has divided the world into those beings that possess reason and therefore immortal souls, and those that do not. The result of this schema has inevitably been disadvantageous to animals who have been regarded as bereft of an interior spiritual life, as well as the benefits of immortality. Christian spirituality has not consciously been at home with the world of non-human creatures—either animal or vegetable. Classic accounts of eternal life as found in Augustine of Hippo (354–430), Thomas Aquinas (c. 1225–1274), or John Calvin (1509–1564) make little or no reference to the world of animals. Animals, it seems, are merely transient or peripheral beings in an otherwise wholly human-centric economy of salvation.

The second idea—common to Christianity, Judaism, and Islam—is that animals, along with vegetables and minerals, exist instrumentally in relation to human beings; they are made for human beings, even belong to human beings, as resources in creation. This idea predates Christianity and is found notably in Aristotle (384–322 B.C.E.), who argues that "since nature makes nothing to no purpose, it must be that nature has made them [animals and plants] for the sake of man" (*The Politics,* 1, viii). This idea, largely unsupported by scripture, was nevertheless taken over by Aquinas, who conceived of creation as a rational hierarchy in which the intellectually inferior existed for the sake of the intellectually superior. Hence Aquinas posits that "It is not wrong for man to make use of them [animals] either by killing or in any other way whatever" (*Summa contra Gentiles,* Third Book, Part II, cvii).

Such instrumentalism, which features rationality as the key factor dividing human beings from "brute beasts," has in turn buttressed the third influence, namely the notion of human superiority in creation. Human superiority need not, by itself, have led to the neglect of animal life, but when combined with the biblical ideas of being made "in the image of God" (Gen. 1: 26–27) and God's preferential choice to become incarnate in human form, some sense of moral as well as theological ascendancy was indicated. As a result, Christianity, and to a lesser extent Judaism, have been characterized historically by an overwhelming concern for humanity in creation rather than an egalitarian concern for all forms of God-given life. That humans are more important than animals, and that they self-evidently merit moral solicitude in a way that animals cannot, has become religious doctrine. Thus the *Catechism of the Catholic Church* (1994) maintains that "it is . . . unworthy to spend money on them [animals] that should as a priority go to the relief of human misery" (para. 2418).

These influences have in turn enabled and justified the scientific exploration of the natural world and specifically the subjection of animals to experimentation. Francis Bacon (1561–1626) pursued his scientific investigations in the belief that humanity should "recover that right over nature which belongs to it by divine bequest" (*Thoughts and Conclusions on the Interpretation of Nature,* IV, p. 294). Since animals were made for human use and are incapable of rationality or the possession of an immortal soul, it was only a short philosophical step to conceive of them as automata devoid of self-consciousness, even incapable of pain. René Descartes (1596–1650) famously likened the movements of a swallow to the workings of a clock, and maintained that "There is no prejudice to which we are more accustomed from our earliest years than the belief that dumb animals think" (*Philosophical Letters,* 1649.). Physiologist Claude Bernard (1813–1878) completed the scientific objectification of animals by pursuing ruthless vivisections of living animals, and inaugurating an era in which experimental science, following theology, became largely blind to the sufferings of nonhuman creatures.

Yet, if science and religion have provided the dominant influences against which animal rights advocates react, they have also variously provided some key justifications for a contemporary animal rights position. Although Charles Darwin (1809–1882) cannot be counted an animal rights advocate (since he shot birds for sport and was not wholly opposed to vivisection), his theory of evolution challenged prevailing religious notions of a difference in kind between humans and animals. In so doing, he laid the foundation for a less hierarchical view of creation and encouraged subsequent discoveries of similarities between species. The irony is that a century of (often abusive) experimental work on animals has demonstrated the range and complexity of their behavior.

It is increasingly difficult to deny self-consciousness, mental states, and emotional complexity to other mammals. Indeed, there is a consensus now among scientists that animals suffer fear, anxiety, trauma, shock, terror, stress, and suffer only to a greater or lesser degree than humans do. Although the case for animal rights does not depend upon any exact similarity between "them" and "us" (except the need for sentiency, defined as the capacity to experience suffering), the question has to be asked: Given what we know now of the similar biological capacities of humans and animals, how can we justify a total difference in our moral treatment of them?

Similarly, religious traditions, especially Christianity, have rekindled more generous insights about animals. Chief among these are the notions that animals too are created by God and have intrinsic value and that human "dominion" over animals means exercising a God-given responsibility of care, and, not least of all, an appreciation that there are moral limits to what humans may do to other creatures. Such a notion of moral limits is explicit in the Hebrew Bible and has formed the basis of the traditional rabbinic injunction not to cause animals unnecessary suffering. Although it came rather late in the day, the humanitarian movement of the nineteenth century in England and the United States focussed religious sensibilities on the suffering of innocents (children as well as animals). Both Christians and Jews, including

Arthur Broome and Lewis Gompertz, were involved in the foundation in London in 1824 of the Society for the Prevention of Cruelty to Animals (SPCA), the world's first national animal welfare organization. Some modern theologians have argued that there is a specifically theological basis for animal rights based on God's prior right as creator to have what is created treated with respect.

Although people in Eastern countries, dominated by the religions of Hinduism, Buddhism, and Jainism, have in practice treated animals with as little respect as people in Western countries, their religions have nevertheless retained notions of respect and nonviolence (*ahimsa*) toward animal, as well as human, life. In the doctrine of *samsara* (reincarnation) a continuity of soulfulness is presupposed (however much it may presuppose a moral hierarchy of life itself), and in Buddhism the first precept against killing is still normative. Specifically, the *bodhisattva's* example of compassionate postponement of buddhahood in order to liberate other suffering beings is a powerful religious ideal expressing the regard that the strong ought to have for the weak.

This ideal also expresses the best in traditional Jewish and Christian theology as summed up in the line that the "good shepherd lays down his life for the sheep" (John 10: 11). Our very God-given power over animals should inspire a view of ourselves not as the "master species but rather as the servant species" (Linzey 1994, p. 45). The irony for animal rights advocates is that traditions that have supported and justified animal abuse also contain within themselves the seeds of an enlightened, even generous, attitude toward the non-human.

See also ARISTOTLE; AUGUSTINE; BUDDHISM; CHRISTIANITY, ROMAN CATHOLIC, ISSUES IN SCIENCE AND RELIGION; DARWIN, CHARLES; DESCARTES, RENÉ; HINDUISM; IMAGO DEI; JUDAISM; PRIMATOLOGY; SOUL; THOMAS AQUINAS

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ANTHROPIC PRINCIPLE

The Anthropic Principle asserts that the existence of human life places certain necessary constraints on cosmological and metaphysical theories. It is an *ex post facto* methodological tool that attempts to relate the structure of the universe to the underlying conditions that are necessary for the existence of observers.

The Anthropic Principle attempts to explain the universe's many life-supporting "coincidences" in two distinct ways: 1) by appealing to an all-encompassing selection effect amongst a variety of universes (e.g., the Weak Anthropic Principle); 2) by asserting that the evolution of life is the necessary outcome of the laws of nature (e.g., the Strong Anthropic Principle). It is this latter form that suggests the possible creative activity of an Intelligent Designer.

Formulated in 1974 by the British astrophysicist Brandon Carter, the Anthropic Principle is an attempt to limit the Copernican dogma, which asserts that the Earth does not occupy a privileged central position in the universe. However, while the Earth may not be special or privileged in *every* way, this does not mean that it cannot be privileged in *any* way. Indeed, Carter pointed out that the location of the Earth in space is "necessarily privileged to the extent of being compatible with our existence as observers" (p. 291).

The Anthropic Principle is controversial because it implies a teleological link between the structure of the universe and the existence of human beings. Several theorists have taken this idea one step further by incorporating the Anthropic Principle into a larger design argument for the existence of God.

Teleology and fine-tuning

The Anthropic Principle makes this type of goal-directed argument possible by highlighting the various prerequisites for the existence of life. When these prerequisites are duly examined, a striking number of "cosmic coincidences" are discovered to exist between distant branches of physics. These anthropic coincidences are noteworthy because they are essential for the existence of life and because they require tremendous "fine-tuning" before they can be operational. The gravitational constant (G), for instance, appears to be exceedingly fine-tuned for the existence of life. If it were slightly larger, stars would have burned too hot and much too quickly to support the fragile needs of life; if it were slightly smaller, the intrastellar process of nuclear fusion would have never initiated, and life would have been incapable of arising on the Earth.

This same rationale can also be applied to the expansion rate of the nascent universe. This crucial factor is determined by the cooperative interplay between several distinct cosmic parameters, including the mass density of the universe, the explosive vigor of the Big Bang, and the strength of the gravitational constant. If the resulting cosmic expansion rate happened to be slightly greater than the presently observed value, life-supporting galaxies would have been unable to form; if it were slightly smaller, the early universe would have collapsed back in on itself shortly after the Big Bang. Either way, no life forms would have been possible.

This is significant, because the various parameters that comprise the cosmic expansion rate also had to be fine-tuned to better than one part in 1060 in order to generate a "flat" universe, so that normal Euclidian geometry (in which the sum of a triangle's three angles adds up to 180 degrees) could then become applicable. A similar degree of fine-tuning can be found throughout the remainder of nature's fundamental parameters.

The challenge is to find a plausible explanation for this fine-tuning. According to the British mathematical physicist Roger Penrose, the odds that a fine-tuned biocentric universe could have accidentally evolved are an astounding one in ten to the 10^{123}, a number so vast that it could not be written on a piece of paper the size of the entire visible universe. This is why many theorists have posited the existence of a "supercalculating intellect" to account for this fine-tuning.

Others, however, have scoffed at this teleological interpretation of cosmological history. They point out that this fine-tuning could have been generated randomly over billions of years if the universe turns out to be merely one of many. In this case, life would have evolved only in those regions that happened to possess the "correct" configuration of fundamental parameters, and human beings would then find themselves living in this special region as a straightforward selection effect. Critics, however, charge that this position is question-begging by its very nature, since it assumes the prior existence of these unexplained worlds.

Definitions

The Anthropic Principle comes in a variety of permutations, each with its own set of implications.

Weak Anthropic Principle. The broadest and least controversial permutation is known as the Weak Anthropic Principle (WAP). Given the reality of human life, the physical universe must contain areas that are compatible with the existence of human beings as observers. The WAP states that humans never could expect to observe a universe that is significantly different from their own, because human existence *depends* on the prior existence of just such a universe. The WAP thus doesn't try to explain how or why the universe came to be life-supporting. It merely notes that, while the universe is biocentric for unknown reasons, given the current existence of humans it couldn't possibly have been otherwise.

One of the advantages of the WAP is that it highlights the many diverse structural parameters that are necessary for the existence of life. Nevertheless, many people find the WAP deeply unsatisfying because it merely states what is already known to be true; namely, that the universe *has* to be structured in its present form before it can be capable of supporting carbon-based life. The WAP is thus incapable of explaining *why* the universe is structured in this biocentric manner.

Strong Anthropic Principle. The more potent Strong Anthropic Principle (SAP) attempts to explain why the universe has a biocentric structure. According to the SAP, the universe must have properties that will allow life to develop within it at some stage of its history. The key element is the word *must;* it means that the universe *had* to be life-supporting at some stage of its history. This possibility is suggested by the many astonishing coincidences between distant branches of physics that all work together, against all the odds, to make life possible. The conventional SAP, however, does not attempt to explain why the universe must be biocentric. It simply states that this must be so.

Design-Centered Anthropic Principle. The SAP thus comes close to positing the existence of a cosmic designer because there doesn't seem to be any other plausible way of explaining why the universe had to be life-supporting. For this reason the physicist Heinz R. Pagels (1939–1988) once quipped that the SAP is "the closest that some atheists can get to God." One interpretation of the SAP explicitly credits a designer for the Earth's many biocentric features. This interpretation, which can be called the Design-Centered Anthropic Principle (DCAP), holds that the universe is biocentric because it was deliberately designed to be this way by a higher power.

Participatory Anthropic Principle. A second version of the SAP, derived from the findings of modern theoretical physics, has been dubbed the Participatory Anthropic Principle (PAP) by physicist John Wheeler (b. 1911). This version holds that observers are necessary to bring the universe into being. The PAP follows from the standard Copenhagen interpretation of quantum mechanics, in which some type of living consciousness is required to make events "real." According to this interpretation, developed by physicist Neils Bohr (1885–1962), there is no such thing as a concrete quantum reality until a living observer exists to "collapse" the appropriate quantum wave function. Without this act of observation, reality seems to be held in a paralyzing state of indecision.

Some theorists have gone so far as to argue that life is necessary to make the universe itself real. The physicist George Greenstein (b. 1940) has conceived of a "symbiotic universe" in which both life and the universe exist in a classic state of symbiosis; the universe provides the physical foundation for the existence of life, and life symbiotically responds by imparting a concrete state of reality to the cosmos.

The problem with this conceptualization is that life did not evolve until billions of years after the

Big Bang. In order for Greenstein's theory to be plausible, a noncorporeal form of life had to have been responsible for observing the universe into being long ago. The only candidate for this role would be the "Ultimate Observer" spoken of by John Barrow and Frank Tipler. This observer alone would have been in a position to observe the entire universe into being.

Final Anthropic Principle. A third version of the SAP has been dubbed the Final Anthropic Principle (FAP). According to FAP, intelligent life must come into existence in the universe, and, once it comes into existence, it will survive forever and become infinitely knowledgeable as it strives to mold the universe to its will. The FAP thus possesses an obvious religious quality because it states that there is a positive universal purpose to human life that cannot be thwarted by any possible power. In this sense, the FAP is analogous to the tenets of generic theism, particularly in its affirmation of an afterlife. However, the FAP does not explain why intelligent life will endure forever. It merely states that it will do so.

Anthropic coincidences

It is important to distinguish between the Anthropic Principle and a curious set of physical facts known as *anthropic coincidences.* The Anthropic Principle proper is a speculative hypothesis regarding the possible role of humanity in the cosmos, whereas the various anthropic coincidences are empirical observations that relate the apparent fine-tuning of the universe to the needs of life. This, in turn, seems to provide some degree of empirical support for certain forms of the Anthropic Principle.

The value of the gravitational constant *G,* the mass density of the universe, and the explosive vigor of the Big Bang have all seemingly been fine-tuned to cooperate with one another to generate a smoothly expanding universe of coherent galaxies, each containing an abundance of medium-sized biocentric stars like the sun. Numerous other fine-tuned anthropic coincidences are also at work in the universe to make life possible. A partial list includes the following:

(1) the values of nature's fundamental constants;
(2) the existence of three spatial dimensions;
(3) the ratio of the electromagnetic force constant to the gravitational constant;
(4) the mass ratio of the electron and proton;
(5) the ratio of protons to electrons;
(6) the cosmic entropy level;
(7) the speed of light;
(8) the age of the universe;
(9) the mass excess of the neutron over the proton;
(10) the initial excess of matter over antimatter; and
(11) the sun's historical change in luminosity, which happened to coincide with the specific needs of Earth-based life forms.

One of the most notable anthropic coincidences was discovered in 1953 by the British astronomer Fred Hoyle (1915–2001), a former atheist. Hoyle had been researching the intrastellar process of carbon synthesis when he stumbled upon a remarkable series of coincidences pertaining to the stepwise assembly of the carbon atom. To his great surprise, Hoyle discovered that the nuclear resonance levels of both carbon and its immediate precursors (helium and beryllium) were fine-tuned to work together to encourage carbon synthesis. He also found that oxygen's nuclear resonance level is half a percent too low to encourage the nuclear conversion of carbon into oxygen. The result of this remarkable series of coincidences is that carbon can be manufactured inside dying stars in sufficient quantities to make organic life possible. Hoyle concluded that the universe is a "put up job," and that a "supercalculating intellect" had to have "monkeyed" with the basic parameters of physics and cosmology. Otherwise, one would never expect so many unrelated and improbable coincidences to work seamlessly together to generate a biocentric universe.

The Anthropic Design argument

Given the many intercoordinated steps that are required to generate a fine-tuned biocentric universe, many theorists find it astonishing that any form of life could have evolved on this planet. There are simply too many ways in which cosmic evolution could have gone wrong with respect to life, particularly given the universality of the Second Law of Thermodynamics, which states that the total amount of disorder in the universe is always increasing. It is the Second Law that leads one to expect a non-biocentric outcome at each stage of the universe-building process, yet the correct biocentric result nevertheless happened at each bifurcation point.

It is the fine-tuning of nature's fundamental constants at the Big Bang that probably enabled this to happen. Indeed, given the brute fact of human existence, it is *necessarily* the case that the universe be fine-tuned enough for it to overcome the many thermodynamic hurdles that naturally exist on the way to life. This, in turn, seems to suggest a strong element of necessity in the universe's underlying ability to generate life. Insofar as this is so, it constitutes evidence in favor of the Strong Anthropic Principle.

Moreover, since the general cosmic tendency is always towards an increased amount of disorder, some thinkers conclude that there must have been some type of constraining force at work in the past. Otherwise, this predisposition towards disorder would likely have put the universe on a non-biocentric path long ago, despite the fact that order can sometimes be generated within an open thermodynamic system by adding energy to it.

Traditional cosmology has been unable to account for this mystery, except insofar as it has used the principle of cumulative selection to explain the successive preservation of small instances of order, each of which possibly could have been random in origin. The problem with this hypothesis is that the universe had to have evolved to a relatively advanced stage before any type of cumulative selection could have taken place. For this reason many find the Strong Anthropic Principle to be compelling. How else can one explain the trillions of correct choices on the way to life, despite the Second Law, if it weren't structurally necessary for the universe to evolve life at some point in its history?

The Weak Anthropic Principle is typically invoked to refute this conclusion. According to this view, humans shouldn't be surprised at their own existence because they are merely experiencing a selection effect, since it is not possible for them to have observed a non-biocentric universe. While this may be so, it does not necessarily follow that human existence is not surprising. In the same way that a condemned criminal facing a one hundred-man firing squad would naturally be surprised if all one hundred rifles misfired simultaneously, it is also appropriate for human beings to be astonished at their own existence.

Many Worlds Interpretation. A potent counterargument to this anthropic viewpoint has been provided by Hugh Everett's (1930–1982) Many Worlds Interpretation of quantum mechanics. According to this hypothesis, there are an infinite number of "compartments" or worlds in existence within a much larger "multiverse," each possessing its own randomly varying set of fundamental constants. Humans therefore shouldn't be surprised at their own existence, because it is only natural for life to evolve in the one region of the multiverse that is capable of supporting its existence. This is a prime example of how the Weak Anthropic Principle can be used within a nontheistic worldview to account for the existence of life.

There are three problems with the Many Worlds approach, however. First, there is no evidence for *any* of these other possible worlds, nor can there be any such evidence in the future because these alternative domains are believed to be utterly beyond human observational powers, even in principle. Secondly, this approach begs the question, since it assumes the prior, unexplained existence of the multiverse itself. Finally, the use of an infinite number of unobservable worlds to explain the existence of our own world is an unprecedented violation of Ockham's Razor, which states that the simplest explanation in any set of natural circumstances is probably the correct one.

Anthropic explanations

Critics of the Anthropic Principle believe it to be scientifically sterile, since it doesn't initially seem to explain much about the cosmos in which humans live. Supporters of the Anthropic Principle, by contrast, believe that it holds the key to an intriguing relationship between the structure of the universe and the existence of human observers. The size and age of the universe provide an excellent case in point. Prior to the advance of modern cosmological science, it was believed that both the physical and temporal dimensions of the universe were unrelated to the existence of living observers. The mathematician and philosopher Bertrand Russell, for instance, believed that the universe's enormous size and age naturally rendered the concept of intelligent design implausible, since one would naturally expect a deity to have created the best things in the world (e.g., human beings) first rather than last.

This viewpoint has been supplanted by modern cosmological findings that indicate that a certain minimum time frame is inherently required for the intrastellar synthesis of carbon by natural evolutionary pathways. The amount of time that is necessary for this outcome amounts to several billion years, which is roughly equivalent to the time required to synthesize carbon and other heavy elements inside dying red giant stars. During this entire carbon-making epoch, though, the universe itself has been relentlessly expanding. Therefore, it is only in a universe that is sufficiently old, and hence sufficiently large, that carbon-based observers can evolve. The enormous size of the visible universe (approximately fifteen billion light years in spatial extent) is thus directly related to the time required for intrastellar carbon synthesis, due to the ongoing cosmic expansion. This is a genuine anthropic explanation because it links several aspects of the universe to the conditions necessary to generate living observers.

Anthropic versus biocentric

The Anthropic Principle is actually a philosophical misnomer, since it is primarily an argument about the centrality of biological life in general. As such, it could legitimately be called the "Biocentric Principle." A separate argument is thus required to generate an Anthropic Principle from the biocentric evidence. The Greek word *anthropos,* however, refers to uniquely human life, so the possible existence of intelligent beings elsewhere would technically invalidate the Anthropic Principle. In order to allow for this possibility, it has been suggested that the Anthropic Principle be renamed the *Humanoid Principle.*

Three distinct arguments are thus conflated within the Anthropic Principle: (1) a biocentric argument, which refers to the centrality of biological life forms in general; (2) a humanoid argument, which refers to the centrality of intelligent humanoid life; and (3) a specific anthropic argument, which argues for the exclusivity of Earth-based intelligent life. These conflations, however, are widely deemed to be irrelevant to the central thrust of the Anthropic Principle, since it is generally assumed that human life would be the ultimate goal of any cosmic intention to evolve Earth-based life. It is also assumed that the possible existence of other humanoid life forms would not invalidate the Anthropic Principle itself. Instead, it would simply provide other cosmic loci by which the biocentric nature of the universe could be explained.

Conclusion

The basic purpose of the Anthropic Principle is to relate the underlying structure of the universe to the fact of human existence. Although many thinkers find this goal unrealistic, others believe that the uniqueness of human consciousness is a fact of fundamental significance in the cosmos. For it is primarily through the vehicle of human awareness that the universe has somehow become aware of itself, and no other known entity appears to possess this marvelous capacity.

See also ANTHROPOCENTRICISM; COPENHAGEN INTERPRETATION; COSMOLOGY, PHYSICAL ASPECTS; DESIGN; ENTROPY; GEOCENTRICISM; MANY-WORLDS HYPOTHESIS; PHYSICS, QUANTUM; THERMODYNAMICS, SECOND LAW OF

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ANTHROPOCENTRISM

Anthropocentrism (human-centered) is a term used to describe certain philosophical perspectives that claim that ethical principles apply to humans only, and that human needs and interests are of the highest value and importance. Anthropocentrism is found in both religious and secular philosophies. In science, anthropocentrism has played an important role in liberating human knowledge from external authorities, and in promoting the interests of humanity as a whole against particular interests. Both scientists and theologians have drawn on anthropocentrism to defend specific views about nature, scientists often on the basis of a perspective on evolution in which humans are considered the highest form of life on Earth, and theologians on the basis of a divinely mandated right for humans to exercise dominion over nature.

Beginning in about 1970, anthropocentrism became common in environmental discourse. Anthropocentric ethics evaluates environmental issues on the basis of how they affect human needs and attaches primary importance to human interests. The term contrasts with various *biocentric* (life-centered) perspectives, which assume that nonhumans are also carriers of moral value.

Anthropocentrism in ethics is found in two main forms: *consequential* ethics and *deontological* ethics. Basic to both is the perception of a discontinuity between humans and the rest of nature. Humans are considered superior to animals for various reasons, including their ability to think and speak, plan, organize projects, and so on. According to the German philosopher Immanuel Kant (1724–1804), humans alone have self-consciousness. Humans are therefore fundamentally different in rank and dignity from all other beings, while animals can be treated as means to human ends. The moral status of humans is thus awarded on the basis of "excellence." Values are grounded in the fact that something is valuable for humans, and so human actions should be valued on the basis of their usefulness for humans.

The basic idea of consequentialist anthropocentrism is that human actions are valued according to their consequences for other humans. In a market-oriented society, consequentialist anthropocentrism is often linked to the idea that problems in relation to society and nature are technical. Both human and natural resources are considered unlimited and available for human consumption. If there is a shortage, then replacement products will always be made available on the basis of the law of supply and demand. High status is awarded to technical products such as buildings, bridges, dams, and highways. The basic premise is the idea that human interests rule the world, and that nature is considered relevant only as a resource to be exploited by humans. If a crisis arises with regard to available resources, it is primarily a technical problem, which can be solved by adjustments. In its simplest form this could mean that humans need to move to a new place. When no new place is available, other measures can be taken, such as moving pollutants to a different place or using technology to get rid of toxic elements. The ideal is "business as usual" for the benefit of humans, modified by ad hoc measures to prevent discomfort for human society. Consequentialist anthropocentrism is also the central approach in policies of resource management that respond to the problem of limited resources by adjusting production and consumption, and by avoiding extreme pollution. The anthropocentric attitude is expressed through the ideals of wise use and sustainable development. The central concern is to secure the demands of the present without endangering future needs.

Deontological anthropocentrism in ethics deals primarily with rights and duties that are carried by ethical subjects or by those affected by intended actions. An important issue is who or what may count as a moral subject. In deontological anthropocentrism, only humans have ethical duties and rights. A major concern is therefore to find reasons why humans alone have qualities that set them apart from all other creatures. This is a difficult task because it is hard to define qualities that include all humans while at the same time excluding other living beings. In the Kantian tradition, the hallmark of humans has been connected to the ability of human beings to take moral demands upon themselves. To be an authentic human being is to exercise the freedom to accept morally binding restrictions on "free" choices of actions, thus rejecting selfishness for the sake of a higher moral rationality. Humans are by virtue of their possibility of free choice a "moral community," distinct from other communities on Earth. From a Kantian perspective, one may have indirect duties towards nonhumans, but such duties are only relevant in so far as they have instrumental importance and ultimately lead toward the promotion of human freedom.

Anthropocentrism is common in the Judeo-Christian tradition and in Islam, in part because God is perceived in anthropomorphic categories, but also because the primary concern of theology is humanity's relation with God (*theological anthropocentrism*). With regard to environmental concerns, theistic traditions affirm that humans have an obligation to treat the natural world with respect and care in much the same way as a farmer cultivates the land (*stewardship ethics*). In some Eastern religions (e.g., Mahayana Buddhism), the salvific interest is more universal. All sentient beings, however, have to reach the level of human existence before they can attain *nirvana*.

Since the 1960s awakening of ecological consciousness, the anthropocentric attitude has been strongly criticized, especially regarding its role in theology and ethics, and in secular science and public policy making. Some have attempted to "soften" anthropocentrism by correcting the perceived misconception of humanity as distinct and separate from the natural world. They have argued that anthropocentric concerns for human well-being should be based on enlightened self-interest in which humans regard themselves as partly constituted by the natural world and pay sufficient attention to sound metaphysics, scientific theories, aesthetic values, and moral ideals. This self-interest will naturally lead to respect for the nonhuman world, thus preventing it from degradation and destruction. Others claim this view to be shallow and assert the need for a total reversal of the anthropocentric perspective, as in *biocentrism,* in which the biotic community is seen as the central concern.

See also DEEP ECOLOGY; ECOLOGY, ETHICS OF; FREEDOM; KANT, IMMANUEL; VALUE, RELIGIOUS; VALUE, SCIENTIFIC

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ROALD E. KRISTIANSEN

ANTHROPOLOGY

Anthropology is the study of humanity, in all its aspects, in all times and all places. In this sense, everyone is an anthropologist, for everyone is curious about themselves and their fellow humans, and people often ask anthropological questions. Anthropology is distinctive not so much in subject as in approach. Much of the character of the field, and the heart of its contribution, have come through ethnographic fieldwork, which comprises a large suite of techniques for studying people in qualitative and quantitative depth, typically while living among them for extended periods. The anthropologist's ideal is to learn a people's language, live with them, observe them in their day to day lives and in special events, all the while taking measurements, listing names, and holding extended discussions about their gods, cosmologies, and opinions of each other. Participant observation in which anthropologists do things with the people they are studying to the extent they allow brings such a wealth of knowledge that many anthropologists spend the rest of their lives discovering new insights from even their first trip to the field.

Themes and approaches

This wealth of information is studied in distinctive ways. Anthropologists are divided on whether the discipline can or even should be considered a science, but even the most scientific anthropologists recognize that a qualitative, interpretive study of ethnographic findings must play a major role. Understanding another group of people involves the search for meaning in what they do and say. The difference between the simple empirical observation that someone's eyelid twitched and understanding what someone was really up to when he winked at another person, entering the web of social relations and subtle meanings behind this little conspiracy, is what Clifford Geertz, following philosopher Gilbert Ryle, calls "thin description versus thick description." Ethnography, he concludes, is thick description. This is also what is needed for any broader, more abstract comparative study in anthropology.

Anthropological questioning is also guided by certain basic concepts or themes, such as *cultural relativism.* Often contrasted with *ethnocentrism,* cultural relativism is the insistence on evaluating customs and ideas in terms of that culture's own values rather than those of another culture. Such an approach is sometimes confused with the different and not particularly viable idea that all customs are of equal practical and moral value. Anthropology seeks to understand, for example, why female circumcision or ritual cannibalism have been so important to certain peoples, and how such practices function within those cultures. Everyone benefits from this greater understanding, but it does not follow that everyone must find these practices acceptable.

A second theme is *holism,* the attempt to comprehend the breadth and depth of what is human and how it fits together. Thus, anthropology's concern is not just with, for example, the economy itself, but with questions such as "How does the economy relate to kinship, status, and political considerations?" and "How do all these together affect what it is like being a woman in such a situation rather than a man?" Anthropology also strives to comprehend the breadth of human cultural, social, and physical variation. For example, compared to the specialized field of economics, anthropology explores the full range of what human economies can be like. Similarly, anthropology seeks to understand the nature of political leadership in the broadest terms, not just by comparing, for example, various types of centralized states (democracy with theocracy with monarchy), but by adding Polynesian and African chiefdoms, Micronesian big-man leadership, and the rise of leaders among less centralized or hierarchical hunter-gatherer societies. Without denying that democracies and monarchies differ, these differences are like shades of red compared to the full spectrum of human possibilities. And knowing as much as possible about the full range of human customs can be helpful in answering questions such as "What is economy?" "What is religion?" and "What is art?" as well as corollary questions such as "In what sense is religion a part of what it means to be human?"

Interestingly, an opposing perspective, usually labeled *particularist,* has occasionally swept the field. During such times the common wisdom is that culture is not an integrated system, and comparison among cultures is inevitably more misleading than helpful. Typologies of culture such as savagery, barbarism, and civilization, or the more recent band, tribe, chiefdom, and state model of neo-evolutionists such as Steward, Service, Fried, and Earle, are scorned as constraining, simplistic, wooden, or even propaganda promoting Western hegemony.

There is also value in balancing holism and high-level comparisons with an emphasis on that which is unique about each known people. Recent anticomparativist trends have been enmeshed in postmodern philosophical concerns, eliciting the same sometimes rancorous arguments found in other fields. But anthropology's expansive ambitions have always been shadowed by occasional epistemological failure of nerve. One does not have to claim that "all human knowledge is impossible" to appreciate the difficulty of demonstrating how deeply human thought is influenced by cultural upbringing, and the difficulty of correctly describing the important depths of another people's culture.

Perspectives toward culture

Probably the field's greatest conceptual contribution to human understanding comes through developing and elaborating the concept of culture. In his *Primitive Culture* (1871), Edward Burnett Tylor introduced the term *culture* into his new science of humanity, which he called *anthropology.* Despite many suggestions for alternative definitions, Tylor's is still popular: "that complex whole which includes knowledge, belief, art, morals, custom and any other capabilities and habits acquired by man as a member of society" (Tylor, p.1). An increasing number of anthropologists prefer not to include behavior within the category, seeing culture as socially transmitted information, or as Geertz puts it, patterns for behavior, not patterns of behavior. This approach avoids the difficulty of explaining culture in terms of itself and highlights the common disparity between what people say and what they do. This approach also reminds us that not all behavior is cultural (for example, blinks vs. winks).

Anthropologists have traditionally understood culture as radically separate from biology. Alfred Kroeber's influential "superorganic" notion views culture as having almost a life of its own, molding each individual far more than the individual molds culture. Franz Boas and his students, including Margaret Mead and Ruth Benedict, set out early in the twentieth century to demonstrate a radical cultural relativism. Mead's *Coming of Age in Samoa* (1928) convinced generations of Americans that even something assumed to be biological and inevitable, such as the rocky period of adolescence, was not experienced in Samoa. Thus, if not all people behave the same way, the reasons must be cultural rather than biological. Derek Freeman has argued convincingly that Mead's conclusion was largely in error, partly as a result of mistaken interpretation, but also because Mead's teenage informants enjoyed playing games with the naïve outsider.

The emphasis on culture, particularly as a variable that is both influential and somewhat independent of biology, is nevertheless an important theme in anthropology. This perspective has also ensured that anthropologists became among the most ardent critics of sociobiology. Along with many reductionistic ideas popular in Western academia, sociobiology puts itself in the strange position of imaginatively crafting reasons we should choose to believe even our cultures are controlled by genes and both imagination and human choice are illusory. Anthropologists do not necessarily defend freedom of the will; a more typical argument is that while humans may be deeply constrained, culture, which is highly symbolic and essentially arbitrary, is as strong a determining influence on the individual as biology.

Nevertheless, interest in biological influences has grown among anthropologists who are exploring a range of approaches from gene-culture coevolution and dual inheritance to memetics. While memetics has its reductionistic aspects (Susan Blackmore has said that culture is a meme's way of replicating itself), in very important ways, memetics recognizes culture as relatively autonomous, beyond either the thought or the biology of the individual.

The search for human universals, an intense preoccupation of anthropology in its early days, but periodically out of favor, has also become more acceptable since the publication of Donald Brown's *Human Universals* in 1991. Brown offers many examples of human traits that are universal, including difficulties during adolescence and the practice of joking. Even examples illustrating how different cultures can be from each other contain elements of universality; for example, people express social respect in an extraordinary variety of ways, but the fundamental idea behind such behaviors is more or less the same. It is, of course, no easy matter to demonstrate that something is truly universal, and attempts to do so have provoked many arguments about whether a certain group of people genuinely constitutes an exception. But the issue itself is of immense importance, for once it is acknowledged that all people have many things in common, the radical individualism and subjectivism of certain philosophies, as well as categorical assertions that, for example, males could never understand females, rich the poor, or one "race" the thinking of someone from another, lose some of their force.

Subdisciplines of anthropology

Despite an emphasis on certain perspectives, methods, and themes, anthropology remains exceptionally broad and has traditionally been divided into subdisciplines. The standard approach in the United States is the "four-field" model:

(1) Physical or biological anthropology involves any study of human physical nature, especially as related to human evolution. Retrospective objections to anthropology's long fascination with race fail to appreciate the contribution of this work to demonstrating the central role of cultural bias in common racial classifications and stereotypes.

(2) Cultural anthropology studies the customs, beliefs, values, social interactions, and physical products (the culture and society) of people known historically or ethnographically. Longstanding goals include studying traditional ways of life before they succumb to modernization, and discovering the fullest possible range of human practice. But it is not simply a matter of collecting exotic customs, nor is cultural anthropology limited to the study of "primitive" peoples. Cultural anthropology attempts to study the full variety of humanity. Also, because the cultural viewpoint of the anthropologist, not just that of the people being studied, is important, the richness of the field grows in part from the fact that there are trained anthropologists from many parts of the world. In the United Kingdom social anthropology, which gives particular emphasis to social relations and social structures, has been very influential from the early work of Malinowski, Firth, Radcliffe-Brown, Evans-Pritchard and Kuper through Rodney Needham, Mary Douglass and many others.

(3) Archaeology has origins in ancient history and the classics, biblical studies, and art history, as well as in the practice of collecting and its institutional cousin, the museum. Most broadly, archaeology is the study of the material remains of humans who lived in the past, and as such it is not always considered a branch of anthropology. Yet archaeologists will often ask anthropological questions, and many view their quest as a cultural anthropology of extinct peoples.

(4) Anthropological linguistics is the anthropological study of human languages, ancient and modern, oral and written. To the extent that an anthropological perspective on linguistics differs from the separate field of linguistics, it will emphasize communication as an element of culture and as a crucial development in human evolution. Archaeologist Colin Renfrew is using linguistics to aid in reconstructing human movements in the past. Language study is also central to work in cognitive evolution.

Anthropology and the science-religion dialogue

Anthropology is not clearly a science, as indicated by the importance of divergent perspectives or schools of thought (social evolutionism, functionalism, historical particularism, cultural materialism, structuralism). It is thus difficult for a scholar of religion to discover the anthropological understanding of a topic. For example, a biblical scholar who painstakingly applies the structuralist insights of Claude Levi-Strauss to a particular text may be surprised and disheartened when her work is ignored by anthropologists sympathetic to Christianity, simply because they are not sympathetic to structuralism.

Anthropology may have more to contribute through its rich body of ethnographic, linguistic, archaeological, and paleoanthropological literature, and through more widely accepted conceptual categories such as culture, holism, and cultural relativism. In some cases the anthropology-religion connection can be put to practical use. Kenneth Pike, Thomas Headland, and others with SIL International (formerly the Summer Institute of Linguistics), for example, are using anthropology to help ensure that translations of the Bible make sense in the local cultural context.

Perhaps most promising is the use of anthropological insights to address issues that grow from theology itself or from the science-religion dialogue. Such issues include sin, human destiny, consciousness, the environment, technology and religion, cognitive evolution, mind-body questions, and the fundamental nature of humanity. The opportunity for the science-religion dialogue to be conducted using questions drawn from theology rather than for theology to follow along and comment on science is potentially of great value.

A striving to understand what it is to be human is a central theme of both anthropology and theology, and systematic theologies often include a major section on the subject. The nineteenth-century Princeton theologian Charles Hodge gave the title *Anthropology* to the second volume of his three-volume *Systematic Theology* (1872), and he devoted some 730 pages to this subject and to salvation. Primary topics included the origins and nature of human beings, the soul, unity of the human race, original state, covenant of works, the fall, sin, and free agency. More than a century later the second volume of Wolfhart Pannenberg's *Systematic Theology* (1991) covers some of the same topics, though in different ways, in no small part because Pannenberg has given serious attention to the findings of academic anthropology, a field that did not exist when Hodge wrote *Systematic Theology*.

Pannenberg is a good model of serious theological engagement with anthropology without allowing the theological agenda to be overwhelmed. This is not an easy balance, for as F. LeRon Shults points out, theology has not come to grips with the changing view of humanity and human origins carefully constructed by anthropology (and evolutionary biology). It is possible for these topics to be explored philosophically, biblically, and in light of the history of theology, but without much contact with the growing anthropological understanding of what it is to be human. Shults, who is a leading expert on Pannenberg's thought, has himself made a major contribution to rethinking the fundamental theological doctrines of human nature, sin, and the image of God in light of anthropology.

Theologian J. Wentzel van Huyssteen is researching Paleolithic cognition to help understand the origins and nature of the human capacity for religion, a topic also being addressed by an interdisciplinary group of scholars organized by biologist William Hurlbut and anthropologist William Durhamat at Stanford University in California. Taking a somewhat different approach, theologian Philip Hefner is engaged in extensive exploration of the theological relevance of sociobiology and biocultural evolution. Hefner suggests that humans should be viewed as "created co-creators." And from a yet different perspective, population geneticist David Wilcox has written a series of articles exploring paleoanthropological findings from a traditionally evangelical, but not creationist, perspective.

Anthropologist Ward Goodenough, perhaps best known for his research on the people of Truk, has written a series of articles for *Zygon* on such subjects as the human capacity for belief. And the biological anthropologist and polymath Solomon Katz has contributed to the understanding of a great range of issues including religion and food, human purpose, and what it means to have a science of humanity. He has also developed and is now working out a model connecting religious change to subsistence change, arguing in particular that a change in religion was an enabler for the Neolithic adoption of agriculture.

See also ANTHROPOLOGY OF RELIGION; CONSCIOUSNESS STUDIES; CREATIONISM; CULTURE, ORIGINS OF; EVOLUTION; EVOLUTION, BIOCULTURAL; FREEDOM; IMAGO DEI; MEMES; MIND-BODY THEORIES; SIN; SOCIOBIOLOGY; TECHNOLOGY

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ANTHROPOLOGY OF RELIGION

No known society is without religion. Anthropologists study this species-wide phenomenon as a human trait or institution, an element of culture, seeking a deep understanding of all, not just the "world," religions and their local significance. From this breadth, anthropologists of religion ask: What is religion? Are there any common elements? How did it originate? Intentionally nontheological, the anthropology of religion is less concerned with, for example, whether ancestor spirits of the New Guinea Maring people really interact with the living people than with how that perception influences culture. Despite the intention of objectivity, a strong thread of philosophical naturalism permeates the field from E. B. Tylor, James Fraser, and Emile Durkheim to Raymond Firth and Stewart Guthrie. Important exceptions include Edward Evans-Pritchard, Victor Turner, and Roy Rappaport.

See also ANTHROPOLOGY; NATURALISM

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ANTI-REALISM

See REALISM

APOLOGETICS

From the Greek roots *apo* and *leg* (*apologia*), the term *apologetics* can be translated as "speech with cause." In the Christian context, apologetics is important in science and religion discourse because it aims to provide religious faith with credibility. Particularly since the seventeenth century, a shared understanding of divine action in the world has progressively diminished due to new, scientific explanations for natural events that were previously accounted for in terms of supernatural agency. Apologetics increasingly incorporates scientific material in recognition of the universal scope of scientific knowledge in contrast to theology's alleged lack of empirical basis. It is a hybrid form of theology that aims to provide credibility for divine revelation under the light of human reason. In theological terms, apologetical literature aims to account for foundational elements in doctrine under the perspective of a religious conversion, while providing a systematic way for that doctrine to be understood. It "is the theoretical and methodical exposition of the reasons for believing in Christianity." (Bouillard, p. 11)

Early Christian apologetics

In historic Christian theology, apologetics has been characterized by skilled, often impassioned rhetoric. In the New Testament, the word *apologia* is translated as a defense of the hope that inspires the believer to remain upright (1 Peter 3:15), and for Paul and Luke, *apologia* is employed in situations of mission or conflict. This usage expands on the Old Testament usage, where it possesses sapiential qualities (Wis. 6:10). In neither case does it connote a legal or even a rigorous philosophical justification of religious faith.

In early Christianity, apologetics arose as a theological response to political crisis and as the theoretical expression for ecclesial community. Early Christian apologetics focused primarily on the significance of the person and work of Jesus Christ in arguments with Jews (as in Justin Martyr's *Dialogue with Trypho*) and later with pagan culture through varying critical incorporations of Platonist and gnostic ideas (as in Origen's *Contra Celsum* or Tertullian's *On Prescription Against Heretics*). Theological arguments turned toward civil authorities regarding the toleration of Christianity until the time of fourth century Roman Emperor Constantine. Early Christian apologetics reached a high point with Augustine of Hippo's *City of God,* and especially *The Literal Meaning of Genesis,* which is often cited in modern attempts to cohere a reading of the biblical text with science.

In the medieval period, apologetics was diverted by the encounter with early Islam, evident through Thomas Aquinas's *Summa Contra Gentiles.* As a result, a theological distinction in religious knowledge between revelation and reason was forged and intensified in a full development of theology as a scientific discipline. Through tensions resonant in early Protestant appeals to natural theology, Calvinist apologetics emerged as a formidable stream of thought that is still manifest in several modern theological schools. Against traditional Aristotelian metaphysics and natural theology, John Calvin's *Institutes of the Christian Religion* (1536) stressed the complete sovereignty of God's Word over the instrumental causes of natural powers.

Science and technology

The rise of science and technology in Europe during the sixteenth and seventeenth centuries brought about a stricter, empirical notion of objectivity, which had a pivotal impact on theological apologetics. Combined with a new reluctance on the part of theologians to refer to Christian revelation, the rise of the natural sciences led to diminished religious grounds for natural philosophy. In this new situation, the religious engagement with Enlightenment reason led to a diversity of theological responses to the new sciences. Since the seventeenth century, apologetic writing has stressed a harmony between science and religion, by selecting or neglecting different aspects of scientific and religious knowledge. Only in the late twentieth century has attention turned to uncovering a method of selection that might fruitfully anticipate ongoing discoveries, updates, and new evaluations for expressing theological knowledge.

Five historical questions are particularly important in illustrating this pattern: Copernicanism, the rise of physico-theology, Darwinism, biblical criticism, and scientism. In each case, the initial theological reaction to new scientific learning was confusion and disagreement, followed by concord and agreement.

First, echoing Augustine's hermeneutic that the biblical text is revealed in a way accessible to the uneducated, Galileo Galilei's *Letter to the Grand Duchess Christina* (1615) was a classic attempt to render Copernican astronomy and Catholicism compatible. No recourse to a natural proof for the existence of God was offered in the Galilean controversy.

Second, adopting contrary positions, in the spirit of William Derham's 1713 work *Physico-theology,* thinkers like Samuel Clarke, John Ray, Nicolas Malebranche, and René Descartes speculated on which fundamental natural principles (mechanics or mathematics) ground a proof for God's existence. Isaac Newton's position was the pivotal argument from design and is found in writings such as the *Opticks* (1704), rather than the crucial *Principia* (1687).

Third, after the mid-nineteenth century, Darwinism took this range of opinion and expanded it further into two discernible currents in the English-language world. Initially, there were those who incorporated the Darwinian mechanism of natural selection and adaptation into theological reflection (Asa Gray, Charles Kingsley, Aubrey Moore). Then, there were those who sought to confront and to critique evolution altogether (Charles Hodge, Samuel Wilberforce).

Fourth, advancing beyond the various attempts by philosophers Immanuel Kant, Friedrich Ernst Schleiermacher, Georg Wilhlem Hegel, and theologian John Henry Newman to reestablish a synthesis in knowledge, was scientific historical biblical criticism (David Strauss, Hermann Reimarus, Albert Schweitzer) and its impact upon biblical hermeneutics. This research and that which followed it quickly eclipsed nineteenth and early twentieth century defense of a historically precise text (Pope Pius IX, Karl Barth).

Fifth, from the middle of the twentieth century, a growing chorus of critique against scientific reductionism or *scientism* has developed within the natural sciences, as positivist assumptions of earlier scientific investigation have been shown to be limited.

Twentieth-century apologetics

Still common in the thought of evangelical Protestants, conservative Catholics, and orthodox Judaism, theological apologetics resembles much historical literature in its continuing reference to Christian doctrines such as incarnation, resurrection, creation, and immortality of the soul. However, in other quarters, apologetics has evolved beyond the focus on doctrine and has transformed itself to accommodate the specialization of knowledge and the secularization of university life. This is reflected in the natural theology offered in the prestigious Gifford Lectures offered at Scottish universities since 1889. In Roman Catholicism since 1950, apologetics has been designated as "fundamental theology." Ecumenism and interfaith dialogue have also shaped the importance and impact of theological apologetics.

Late twentieth-century apologetic literature with a scientific accent and doctrinal focus is represented in the writings of the scientist-theologians Stanley Jaki, Alister McGrath, Arthur Peacocke, John Polkinghorne, Robert John Russell, and Thomas Torrance. A less precise theological reconstruction of apologetics exists. It transposes Christian doctrine philosophically through a capacious theoretical commitment. This method is present in the writings of scientists such as Pierre Teilhard de Chardin and Alfred North Whitehead, contemporary philosophers Nancey Murphy, Joseph Bracken, and Holmes Rolston III, as well as the theologians Wolfhart Pannenberg and John Haught.

See also NATURAL THEOLOGY

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PAUL ALLEN

AQUINAS, THOMAS

See THOMAS AQUINAS

ARISTOTLE

The great monotheistic religions have regarded Aristotle's philosophy with both appreciation and hostility. Christian, Islamic, and Jewish theologians generally approved of his well-ordered, teleological world in which final causes ordained that natural processes were directed toward the fulfillment of particular ends. Yet Aristotle rejected various important monotheistic tenants, including the belief that God is the ultimate cause of the existence of the world, the resurrection of the body, and the full immortality of the soul. As unqualified believers in these latter doctrines, Christians were particularly compelled to repudiate Aristotle. Theologians thus tended to reject or reinterpret what they took to be Aristotle's offensive opinions while generally accepting his larger natural philosophy.

Life and work

Aristotle was born in the town of Chalcidice in northern Greece in 384 B.C.E. His father was a physician to the King of Macedon. In 367, at the age of seventeen, Aristotle was sent to Athens to study at Plato's Academy, where he remained for twenty years, until Plato's death in 347. Since he was not chosen to replace Plato as the head of the Academy, Aristotle began a period of travel in Asia Minor, living for awhile in Assos (where he married a woman named Pythias) and then Lesbos until 342, when he accepted King Philip of Macedon's invitation to tutor his son, the future Alexander the Great, then fourteen years old. When Alexander succeeded his father as ruler in 335, Aristotle returned to Athens where he founded his famous school, the Lyceum. Thus began Aristotle's most productive period, which endured until 323, when news of the death of Alexander the Great provoked anti-Macedonian feelings in Athens. A false charge of impiety was made against Aristotle, who then fled Athens to Chalcis in Euboea, where he died in the following year, at the age of sixty-two.

It would be difficult to exaggerate the importance of Aristotle in the history of Western civilization. Not only were his numerous works a dominant factor in at least three civilizations (the Byzantine Empire, Islam, and the Latin West) using three different languages (Greek, Arabic, and Latin, respectively), but his works and ideas remained influential for approximately two thousand years. Aristotle's enormous influence derives not only from his overall brilliance, but also from the fact that he wrote treatises on a remarkable range of topics, which included metaphysics, logic, natural philosophy, biology, ethics, psychology, rhetoric, poetics, politics, and economics (or household management). He is regarded as the founder of two disciplines, logic and biology. The first book of Aristotle's *Metaphysics* is the first history of philosophy as well as the first history of science, while his *Posterior Analytics* is regarded as the first treatise on the philosophy, or methodology, of science. Finally, in six or seven treatises, Aristotle described the structure and operation of the world, thereby formulating a natural philosophy that served as the primary guide for natural philosophers from late antiquity to the seventeenth century in Western Europe, when it was displaced by a new world view associated with Nicolaus Copernicus, Galileo Galilei, Isaac Newton, and many others.

Aristotle reveals a scientific temperament in all his treatises, always emphasizing reason and reasoned argument. He was highly analytic, dividing and categorizing before arriving at important principles and generalizations. He always gives the impression of objectivity and detachment. In coping with any particular problem, Aristotle considered alternative solutions as carefully as possible before resolving the problem.

Aristotle and the divine

Aristotle's views about religion and divinity play a role in his overall conception of the cosmos and its workings. In Book Eight of his *Physics,* he describes what he calls the "Unmoved Mover" or "Prime Mover," which is the ultimate source, or cause, of motion in the universe, but is itself unmoved. For Aristotle this is God, who dwells at the circumference of the universe and causes motion by being loved. The closer to the Unmoved Mover a body is, the more quickly it moves. Although the Unmoved Mover is God, it did not create the world, which Aristotle regarded as uncreated and eternal. As the prime mover, God enjoys the best kind of life, being completely unaware of anything external to itself and, being the most worthy object of thought, thinks only of itself.

Aristotle's God was clearly not a divinity to be worshipped. Apart from serving as the ultimate source of motion, God, ignorant of the world's existence, could play no meaningful role in Aristotle's natural philosophy. Nevertheless, Aristotle seems to have had a strong sense of the divine, which manifested itself in a sense of wonderment and reverence for the universe.

Aristotle's sense of God was unacceptable to Christians, Muslims, and Jews. Although Plato's concept of a God who created from pre-existent matter was also unacceptable, it was far more palatable to monotheists than was Aristotle's Unmoved Mover, who did not create the world. Indeed, it could not have created the world because, argued Aristotle, the world is eternal, without beginning or end. Aristotle insisted that the material world could not have come into being from another material entity, say *B*. For if it did, one would have to ask from whence did *B* come? Such an argument would lead to the absurdity of an infinite regression, prompting Aristotle to argue that the world has always existed, an interpretation that posed further problems for Muslims and Christians. Consistent with his assumption of an eternal world, Aristotle regarded creation from nothing as impossible.

Aristotle's concept of nature was fully compatible with those of the major religions. Indeed he provided basic interpretations that were widely adopted. Aristotle distinguished four operative causes in nature:

(1) the material cause, or that from which something is composed;

(2) the efficient cause, or the agent that made something come into being;

(3) the formal cause, or the characteristics that make it what it is; and

(4) the final cause, or the purpose for which something exists.

It is the last cause that makes Aristotle's system teleological. Although he did not believe that conscious purposes existed in nature, he was convinced that processes in nature aim toward an end or goal and that "nature does nothing in vain." It is therefore appropriate to characterize Aristotle's natural philosophy and science as teleological, a view of nature's operations that fits nicely into the Christian conception of God's creation.

The manner in which Aristotle argued and rendered judgments provoked Christian theologians in the Middle Ages. On a number of issues, Aristotle produced arguments about the physical world that led him to conclude the impossibility of certain phenomena. For example, in the fourth book of *Physics,* Aristotle argued that the existence of a vacuum is impossible inside or outside of our world. Space is always full of matter, which resists the motion of bodies. In the absence of matter in a vacuum, resistance to motion of any kind would be impossible. Without resistance to its motion, a body would move instantaneously, which is impossible.

In the first book of his treatise *On the Heavens,* Aristotle showed the impossibility of the existence of other worlds. Our world, Aristotle argued, contains all the matter there is, with no surplus left to form one or more other worlds, from which he concludes that "there is not now a plurality of worlds, nor has there been, nor could there be."

Aristotle also argued that without exception all accidental properties—that is, properties that are not essential for the existence of a thing—such as colors, the height of an individual, the size of one's foot, and so on, had of necessity to inhere in the substances of which they were the property. It was impossible that an accidental property exist independently of its subject.

In these, and similar instances, Christians were alarmed at the implications of Aristotle's arguments, for it seemed to place limits on God's absolute power to do whatever God pleased, short of a logical contradiction. Did those who accepted Aristotle's natural philosophy and metaphysics believe that God could not supernaturally create a vacuum just because Aristotle had argued that it was naturally impossible? Did they believe that God could not create other worlds if God wished, simply because Aristotle had argued that other worlds were impossible? And did they regard Aristotle's argument as unqualifiedly true when he declared it impossible that accidents of a substance could exist independently of that substance? The latter claim violated the doctrine of the Eucharist, namely that when God transforms the bread and wine of the Mass into the body and blood of Christ, the accidents of the bread and wine continue to exist without inhering in any substances. The uneasiness with limitations on God's absolute power led theologians in the thirteenth century to place restrictions on Aristotle's natural philosophy. Despite the attempt to circumscribe Aristotle's ideas, the effort did not in any way dampen the enthusiasm with which his works were received in the Latin West, where, during the fourteenth to early seventeenth centuries, they functioned as the curriculum in the arts faculties of virtually all of the sixty to seventy universities that had come into existence by that time.

Conclusion

Why did the works of Aristotle become so popular in the West despite the many ideas he had proposed that were offensive to Christians and Christianity? The answer is quite simple: His collected works ranged over many themes and subjects and were therefore too valuable to ignore. Moreover, no rival body of literature existed that could pose even a remote challenge to it. By the early seventeenth century, however, numerous new currents of thought came together to subvert Aristotle's natural philosophy, which was largely overwhelmed and by-passed by the end of the seventeenth century.

See also GALILEO GALILEI; GOD; ISLAM; METAPHYSICS; NEWTON, ISAAC; PLATO; TELEOLOGY

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EDWARD GRANT

ART, ORIGINS OF

Some thirty-three thousand years ago a human being living in what is now Germany carved a figure like a man with a lion's head from a piece of mammoth tusk. Other ivory figurines were made nearby—felines, horses, bison, and mammoth—some with incised markings. Personal decorations appear even earlier. Some beads made from shells from distant shores indicate something special about the materials themselves. Some of the paintings in Chauvet Cave in France have been dated to thirty thousand years before the present, and other cave art may be just as old. Painted slabs from South Africa's Apollo Cave are more than twenty-seven thousand years old, and Australian wall engravings, though less securely dated, may be forty thousand years old. Early Aurignacian sites from thirty-two thousand years ago have produced multiholed bone flutes. Percussion instruments are nearly as old. Footprints beaten into the floors of some Paleolithic caves may suggest dancing.

Over twelve thousand items of Paleolithic portable art have been found in Western Europe alone. There are now three hundred decorated cave sites known, some with only a handful of figures, others with thousands. Humans have been producing art for at least three hundred centuries, portable and parietal, in varied materials, and in widely separate parts of the world. Unfortunately, it is not clear how much this knowledge reveals about the origins of art.

Temporal beginnings and the nature of art

Even asking where and when art began is more complicated than it seems. Because researchers depend on the vagaries of preservation and sometimes chance discovery, it is likely that many other works were created but not (yet) found. Even Chauvet Cave was unknown before 1994. A further complication concerns what qualifies as art or can be conceived as a "precursor" to art. The zoologist Jane Goodall observed wild chimpanzees engaged in a kind of rain dance. Desmond Morris found that apes like to paint—they do so without rewards—and their paintings show balance, control, and varied themes. John Pfeiffer detected among *Homo habilis* (an extinct member of the human genus that lived in Africa approximately 2.5 million years ago) a possible a preference for green lava and smooth pink pebbles, and the geologist and anthropologist Kenneth Oakley notes that fossils that may have been used as charms are common in Paleolithic sites. A rough female form on a pebble from Berekhat Ram, Israel, dated to 230,000 years ago. Is this art or our own imagination? The amazingly early date makes it both more interesting and more difficult to accept.

Art is not easily defined. Robert Layton notes an imprecise, shifting boundary, and different approaches that are hard to correlate, especially with regard to the aesthetic perspective and to art as communication. Anthropologists now commonly shy away from using the term *art.* Margaret Conkey and Olga Soffer advocate not thinking of these images as art but studying them as examples of human symbolic behavior. Some forms of art, such as song, dance, and storytelling, are transient, but other art is more enduring, separating communication from the constraints of time and location. External symbolic storage is of inestimable value in human history, and the arts were among the first media so used.

Sources of art: cogitations, motivations, adaptations, and inspirations

Just as fundamental as the timing and context of its first appearance are the sources from which art arose. Steven Mithin believes the dramatic development of culture, seen in some places as early as fifty thousand years ago and established wherever humans lived by thirty thousand years ago, represents a major redesign of the human mind. The premodern mind had consisted of a suite of relatively separate, specialized intelligences (social, linguistic, natural historical, technical) and the rapid appearance of art and religion is evidence that a generalized intelligence, similar to that of modern humans, allowed people to combine thoughts from the formerly separate intelligences.

Psychological explanations had proliferated even by 1900 when Yrjö Hirn's *The Origins of Art* reviewed many suggestions, from James Mark Baldwin's "self-exhibiting impulse" to Hirn's own preference for locating the art impulse in the human tendency to externalize feeling states, heightening the pleasure and relieving the pain of these feelings and awakening similar feelings in others. The nineteenth-century Russian novelist Leo Tolstoy similarly saw art as a communication of feelings, dependent upon and nurturing empathy. Jumping ahead many years and theories, Nancy Aiken also attributes the origins of art to its emotional effects. This need not involve beauty but could engage any emotion. Some of the same stimuli (lines, shapes) that naturally trigger reactions are used in art to trigger emotional responses that are evaluated as aesthetic. This connection with biologically built-in responses accounts for the universality of the human aesthetic response.

Many models are *selectionist,* proposing more or less plausible scenarios for how art aids adaptation and so is increasingly favored in early populations. Charles Darwin suggested that the ability to create feelings with music gave certain individuals an edge in attracting mates. Interestingly, his fellow discoverer of natural selection, Alfred Russel Wallace, believed natural selection could not account for artistic faculties and proposed a "spiritual essence," a kind of God-of-the-gaps view of human development. Some arguments involve ecological adaptation rather than the psychology of emotion or sexual selection. Pfeiffer proposed that art arose out of necessity to hold the group together, reduce conflict, and pass on a growing body of wisdom. Looking back, art is an advance, but Terrence Deacon believes it was really a desperate response to change, perhaps to a degrading environment. Such models seem to take a pessimistic view of human freedom and creativity, yet wracking one's brains for a solution takes as much creativity as dreaming on a sunny afternoon.

Ellen Dissanayake's ethological approach involves finding core behaviors that natural selection could work on. Most important is "making special," through which reality is elaborated, reformed, and placed in a different realm, usually a magical or supernatural world, though often today a purely aesthetic realm. In contrast Helena Cronin suggests a pre-adaptation route in which art arose as an unselected by-product of some other adaptation. This may be true of many potentials of the human mind, some of which, perhaps, have yet to be discovered.

John Barrow pushes the causal nexus with the fascinating notion that the structure of the universe itself helped shape human creativity and aesthetic sense. Scale is important—if people were the size of ants, they would lack the strength to break chemical bonds as they do when chipping stones or carving ivory. Human associations of colors with emotions may relate to properties of light. Barrow also attempts to trace some aesthetic preferences to human adaptation to an ancestral savanna homeland. While intriguing, however, there really was no single "ancestral environment" upon which to base such an argument. Indeed, Rick Potts convincingly argues that the time of human evolution was marked by intense environmental variability and that the flexible cognition of human beings was an adaptation to instability. Perhaps human creativity and the aesthetic sense also developed in response to environmental instability.

Or did the arts grow from the human need to impose order on human intelligence and its capacity for self-revelation? Once human beings "left the garden," they needed art to cope with their new knowledge, for natural selection could not keep up. In thus recognizing art's connection with the deepest questioning of humans, sociobiologist Edward O. Wilson offers an almost theological argument, though his aim is *consilience,* the interlocking of causal explanations across disciplines.

Because of the human predicament Wilson captures so well, the arts have been deeply connected with religion. Much of the world's art is religious and so are many interpretations. Returning to the caves, the most influential is the idea, championed by the Abbé Breuil, that the art was involved in hunting magic. Structuralism, via Annette Laming-Emperaire and André Leroi-Gourhan, has also been important. Whatever one thinks of structuralism, art is deeply symbolic, and its meaning not easily perceived from another culture. David Lewis-Williams notes that Leonardo da Vinci's *Last Supper* has little to do with men eating. And for Clifford Geertz, the cultural significance of art is a "local matter." Jean Clottes and Lewis-Williams argue for a connection with shamanism in which the caves are spaces for ritual such as making images expressing the trance and hallucinatory experiences of shamanic activity.

Noting Jeremy Begbie's defense of art as knowledge, John Polkinghorne sees art as a vehicle for access to truth, a view not uncommon among artists and writers such as Madeleine L'Engle, C. S. Lewis, Larry Woiwode, and John Keats, who famously wrote in *Ode on a Grecian Urn* that "Beauty is truth, truth beauty." Ursula Goodenough also sees in art a source of nobility, grace, and pleasure, and Thomas Dubay notes that even in mathematics and science, beauty is evidence for truth. Beauty and art are not coextensive but surely related. Polkinghorne points out "That a temporal succession of vibrations in the air can speak to us of eternity is a fact that must be accommodated in any adequate account of reality" (p. 45). Intimations of truth and contact with eternity are powerful motivations. In art and music, like religion, there is a dimension of reality that transcends the material world. Indeed, Alejandro García-Riviera suggests that if God is truth, goodness, and beauty, experience of these is an experience of God.

Interlocking causal explanations

An interlocking of explanations may be crucial for understanding the origins of art. Theological perspectives are not necessarily at odds with other ideas, and they may add an important dimension to theories of art's causation and motivation. Art as a window onto truth not otherwise apprehended makes sense of the deepest experience of art. It is a motivation for "making special" and may also be why the shaman creates art after one spiritual journey as an aid to the next. In some models, this "truth" consists in the capture and communication of an experience or feeling. This also makes sense, for whatever their *ultimate* sources, revelations and intimations come to an artist through experiences or feelings dependent on the human nervous and cognitive systems. And by whatever route, people have natural selection to thank for this wonderful facility for exploring truth. It is the universality of certain human experiences and certain truths so conveyed that allows (some) art to communicate across generations. Lascaux, arguably the most famous of the painted prehistoric caves in France, still conveys real truth, very possibly some of what the artists had in mind, if only in the back of their minds, so many centuries ago.

See also ANTHROPOLOGY; CULTURE, ORIGINS OF; PALEOANTHROPOLOGY

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ARTIFICIAL INTELLIGENCE

Artificial intelligence (AI) is the field within computer science that seeks to explain and to emulate, through mechanical or computational processes, some or all aspects of human intelligence. Included among these aspects of intelligence are the ability to interact with the environment through sensory means and the ability to make decisions in unforeseen circumstances without human intervention. Typical areas of research in AI include game playing, natural language understanding and synthesis, computer vision, problem solving, learning, and robotics.

The above is a general description of the field; there is no agreed upon definition of artificial intelligence, primarily because there is little agreement as to what constitutes intelligence. Interpretations of what it means to be intelligent vary, yet most can be categorized in one of three ways. Intelligence can be thought of as a quality, an individually held property that is separable from all other properties of the human person. Intelligence is also seen in the functions one performs, in actions or the ability to carry out certain tasks. Finally, some researchers see intelligence as a quality that can only be acquired and demonstrated through relationship with other intelligent beings. Each of these understandings of intelligence has been used as the basis of an approach to developing computer programs with intelligent characteristics.

First attempts: symbolic AI

The field of AI is considered to have its origin in the publication of British mathematician Alan Turing's (1912–1954) paper "Computing Machinery and Intelligence" (1950). The term itself was coined six years later by mathematician and computer scientist John McCarthy (b. 1927) at a summer conference at Dartmouth College in New Hampshire. The earliest approach to AI is called *symbolic* or *classical* AI and is predicated on the hypothesis that every process in which either a human being or a machine engages can be expressed by a string of symbols that is modifiable according to a limited set of rules that can be logically defined. Just as geometry can be built from a finite set of axioms and primitive objects such as points and lines, so symbolicists, following rationalist philosophers such as Ludwig Wittgenstein (1889–1951) and Alfred North Whitehead (1861–1947), predicated that human thought is represented in the mind by concepts that can be broken down into basic rules and primitive objects. Simple concepts or objects are directly expressed by a single symbol while more complex ideas are the product of many symbols, combined by certain rules. For a symbolicist, any patternable kind of matter can thus represent intelligent thought.

Symbolic AI met with immediate success in areas in which problems could be easily described using a limited domain of objects that operate in a highly rule-based manner, such as games. The game of chess takes place in a world where the only objects are thirty-two pieces moving on a sixty-four square board according to a limited number of rules. The limited options this world provides give the computer the potential to look far ahead, examining all possible moves and countermoves, looking for a sequence that will leave its pieces in the most advantageous position. Other successes for symbolic AI occurred rapidly in similarly restricted domains such as medical diagnosis, mineral prospecting, chemical analysis, and mathematical theorem proving.

Symbolic AI faltered, however, not on difficult problems like passing a calculus exam, but on the easy things a two year old child can do, such as recognizing a face in various settings or understanding a simple story. McCarthy labels symbolic programs as brittle because they crack or break down at the edges; they cannot function outside or near the edges of their domain of expertise since they lack knowledge outside of that domain, knowledge that most human "experts" possess in the form of what is known as common sense. Humans make use of general knowledge—the millions of things that are known and applied to a situation—both consciously and subconsciously. Should it exist, it is now clear to AI researchers that the set of primitive facts necessary for representing human knowledge is exceedingly large.

Another critique of symbolic AI, advanced by Terry Winograd and Fernando Flores in their 1986 book *Understanding Computers and Cognition* is that human intelligence may not be a process of symbol manipulation; humans do not carry mental models around in their heads. Hubert Dreyfus makes a similar argument in *Mind over Machine* (1986); he suggests that human experts do not arrive at their solutions to problems through the application of rules or the manipulation of symbols, but rather use intuition, acquired through multiple experiences in the real world. He describes symbolic AI as a "degenerating research project," by which he means that, while promising at first, it has produced fewer results as time has progressed and is likely to be abandoned should other alternatives become available. This prediction has proven fairly accurate. By 2000 the once dominant symbolic approach had been all but abandoned in AI, with only one major ongoing project, Douglas Lenat's Cyc (pronounced "psych"). Lenat hopes to overcome the general knowledge problem by providing an extremely large base of primitive facts. Lenat plans to combine this large database with the ability to communicate in a natural language, hoping that once enough information is entered into Cyc, the computer will be able to continue the learning process on its own, through conversation, reading, and applying logical rules to detect patterns or inconsistencies in the data Cyc is given. Initially conceived in 1984 as a ten-year initiative, Cyc has not yet shown convincing evidence of extended independent learning.

Functional or weak AI

In 1980, John Searle, in the paper "Minds, Brains, and Programs," introduced a division of the field of AI into "strong" and "weak" AI. Strong AI denoted the attempt to develop a full human-like intelligence, while weak AI denoted the use of AI techniques to either better understand human reasoning or to solve more limited problems. Although there was little progress in developing a strong AI through symbolic programming methods, the attempt to program computers to carry out limited human functions has been quite successful. Much of what is currently labeled AI research follows a functional model, applying particular programming techniques, such as knowledge engineering, fuzzy logic, genetic algorithms, neural networking, heuristic searching, and machine learning via statistical methods, to practical problems. This view sees AI as advanced computing. It produces working programs that can take over certain human tasks. Such programs are used in manufacturing operations, transportation, education, financial markets, "smart" buildings, and even household appliances.

For a functional AI, there need be no quality labeled "intelligence" that is shared by humans and computers. All computers need do is perform a task that requires intelligence for a human to perform. It is also unnecessary, in functional AI, to model a program after the thought processes that humans use. If results are what matters, then it is possible to exploit the speed and storage capabilities of the digital computer while ignoring parts of human thought that are not understood or easily modeled, such as intuition. This is, in fact, what was done in designing the chess-playing program Deep Blue, which in 1997 beat the reigning world chess champion, Gary Kasparov. Deep Blue does not attempt to mimic the thought of a human chess player. Instead, it capitalizes on the strengths of the computer by examining an extremely large number of moves, more moves than any human player could possibly examine.

There are two problems with functional AI. The first is the difficulty of determining what falls into the category of AI and what is simply a normal computer application. A definition of AI that includes any program that accomplishes some function normally done by a human being would encompass virtually all computer programs. Nor is there agreement among computer scientists as to what sorts of programs should fall under the rubric of AI. Once an application is mastered, there is a tendency to no longer define that application as AI. For example, while game playing is one of the classical fields of AI, Deep Blue's design team emphatically states that Deep Blue is not artificial intelligence, since it uses standard programming and parallel processing techniques that are in no way designed to mimic human thought. The implication here is that merely programming a computer to complete a human task is not AI if the computer does not complete the task in the same way a human would.

For a functional approach to result in a full human-like intelligence it would be necessary not only to specify which functions make up intelligence, but also to make sure those functions are suitably congruent with one another. Functional AI programs are rarely designed to be compatible with other programs; each uses different techniques and methods, the sum of which is unlikely to capture the whole of human intelligence. Many in the AI community are also dissatisfied with a collection of task-oriented programs. The building of a general human-like intelligence, as difficult a goal as it may seem, remains the vision.

A relational approach

A third approach is to consider intelligence as acquired, held, and demonstrated only through relationships with other intelligent agents. In "Computing Machinery and Intelligence" (1997), Turing addresses the question of which functions are essential for intelligence with a proposal for what has come to be the generally accepted test for machine intelligence. An human interrogator is connected by terminal to two subjects, one a human and the other a machine. If the interrogator fails as often as he or she succeeds in determining which is the human and which the machine, the machine could be considered as having intelligence. The Turing Test is not based on the completion of tasks or the solution of problems by the machine, but on the machine's ability to relate to a human being in conversation. Discourse is unique among human activities in that it subsumes all other activities within itself. Turing predicted that by the year 2000, there would be computers that could fool an interrogator at least thirty percent of the time. This, like most predictions in AI, was overly optimistic. No computer has yet come close to passing the Turing Test.

The Turing Test uses relational discourse to demonstrate intelligence. However, Turing also notes the importance of being in relationship for the acquisition of knowledge or intelligence. He estimates that the programming of the background knowledge needed for a restricted form of the game would take at a minimum three hundred person-years to complete. This is assuming that the appropriate knowledge set could be identified at the outset. Turing suggests that rather than trying to imitate an adult mind, computer scientists should attempt to construct a mind that simulates that of a child. Such a mind, when given an appropriate education, would learn and develop into an adult mind. One AI researcher taking this approach is Rodney Brooks of the Massachusetts Institute of Technology, whose lab has constructed several robots, including Cog and Kismet, that represent a new direction in AI in which embodiedness is crucial to the robot's design. Their programming is distributed among the various physical parts; each joint has a small processor that controls movement of that joint. These processors are linked with faster processors that allow for interaction between joints and for movement of the robot as a whole. These robots are designed to learn tasks associated with human infants, such as eye-hand coordination, grasping an object, and face recognition through social interaction with a team of researchers. Although the robots have developed abilities such as tracking moving objects with the eyes or withdrawing an arm when touched, Brooks's project is too new to be assessed. It may be no more successful than Lenat's Cyc in producing a machine that could interact with humans on the level of the Turing Test. However Brooks's work represents a movement toward Turing's opinion that intelligence is socially acquired and demonstrated.

The Turing Test makes no assumptions as to how the computer arrives at its answers; there need be no similarity in internal functioning between the computer and the human brain. However, an area of AI that shows some promise is that of neural networks, systems of circuitry that reproduce the patterns of neurons found in the brain. Current neural nets are limited, however. The human brain has billions of neurons and researchers have yet to understand both how these neurons are connected and how the various neurotransmitting chemicals in the brain function. Despite these limitations, neural nets have reproduced interesting behaviors in areas such as speech or image recognition, natural-language processing, and learning. Some researchers, including Hans Moravec and Raymond Kurzweil, see neural net research as a way to reverse engineer the brain. They hope that once scientists can design nets with a complexity equal to the human brain, the nets will have the same power as the brain and develop consciousness as an emergent property. Kurzweil posits that such mechanical brains, when programmed with a given person's memories and talents, could form a new path to immortality, while Moravec holds out hope that such machines might some day become our evolutionary children, capable of greater abilities than humans currently demonstrate.

AI in science fiction

A truly intelligent computer remains in the realm of speculation. Though researchers have continually projected that intelligent computers are immanent, progress in AI has been limited. Computers with intentionality and self consciousness, with fully human reasoning skills, or the ability to be in relationship, exist only in the realm of dreams and desires, a realm explored in fiction and fantasy.

The artificially intelligent computer in science fiction story and film is not a prop, but a character, one that has become a staple since the mid-1950s. These characters are embodied in a variety of physical forms, ranging from the wholly mechanical (computers and robots) to the partially mechanical (cyborgs) and the completely biological (androids). A general trend from the 1950s to the 1990s has been to depict intelligent computers in an increasingly anthropomorphic way. The robots and computers of early films, such as Maria in Fritz Lang's *Metropolis* (1926), Robby in Fred Wilcox's *Forbidden Planet* (1956), Hal in Stanley Kubrick's *2001: A Space Odyssey* (1968), or R2D2 and C3PO in George Lucas's *Star Wars* (1977), were clearly constructs of metal. On the other hand, early science fiction stories, such as Isaac Asimov's *I, Robot* (1950), explored the question of how one might distinguish between robots that looked human and actual human beings. Films and stories from the 1980s through the early 2000s, including Ridley Scott's *Blade Runner* (1982) and Stephen Spielberg's *A.I.* (2001), pick up this question, depicting machines with both mechanical and biological parts that are far less easily distinguished from human beings.

Fiction that features AI can be classified in two general categories: cautionary tales (*A.I., 2001*) or tales of wish fulfillment (*Star Wars*; *I, Robot*). These present two differing visions of the artificially intelligent being, as a rival to be feared or as a friendly and helpful companion.

Philosophical and theological questions

What rights would an intelligent robot have? Will artificially intelligent computers eventually replace human beings? Should scientists discontinue research in fields such as artificial intelligence or nanotechnology in order to safeguard future lives? When a computer malfunctions, who is responsible? These are only some of the ethical and theological questions that arise when one considers the possibility of success in the development of an artificial intelligence. The prospect of an artificially intelligent computer also raises questions about the nature of human beings. Are humans simply machines themselves? At what point would replacing some or all human biological parts with mechanical components violate one's integrity as a human being? Is a human being's relationship to God at all contingent on human biological nature? If humans are not the end point of evolution, what does this say about human nature? What is the relationship of the soul to consciousness or intelligence? While most of these questions are speculative in nature, regarding a future that may or may not come to be, they remain relevant, for the way people live and the ways in which they view their lives stand to be critically altered by technology. The quest for artificial intelligence reveals much about how people view themselves as human beings and the spiritual values they hold.

See also ALGORITHM; ARTIFICIAL LIFE; CYBERNETICS; CYBORG; IMAGO DEI; THINKING MACHINES; TURING TEST

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NOREEN L. HERZFELD

ARTIFICIAL LIFE

Artificial life is a cross-disciplinary field of research devoted to the study and creation of lifelike structures in various media (computational, biochemical, mechanical, or combinations of these). A central aim is to model and even realize emergent properties of life, such as self-reproduction, growth, development, evolution, learning, and adaptive behavior. Researchers of artificial life also hope to gain general insights about self-organizing systems, and to use the approaches and principles in technology development.

Evolution of research

The historical and theoretical roots of the field are manifold. These roots include:

- early attempts to imitate the behavior of humans and animals by the invention of mechanical automata in the sixteenth century;
- cybernetics as the study of general principles of informational control in machines and animals;
- computer science as theory and the idea of abstract equivalence between various ways to express the notion of computation, including physical instantiations of systems performing computations;
- John von Neumann's so-called self-reproducing Cellular Automata;
- computer science as a set of technical practices and computational architectures;
- artificial intelligence (AI)
- robotics;

- philosophy and system science notions of levels of organization, hierarchies, and emergence of new properties;
- non-linear science, such as the physics of complex systems and chaos theory; theoretical biology, including abstract theories of life processes; and
- evolutionary biology.

Despite the field's long history, the first international conference for artificial life was not held until 1987. The conference was organized by the computer scientist C. G. Langton, who sketched a future synthesis of the field's various roots and formulated important elements of a research program.

In the first five years after 1987, the research went through an exploratory phase in which it was not always clear by what criteria one could evaluate individual contributions, and some biologists were puzzled about what could falsify a specific piece of research. Later the field stabilized into clusters of research areas, each with it own models, questions, and works in progress. As in artificial intelligence research, some areas of artificial life research are mainly motivated by the attempt to develop more efficient technological applications by using biologic inspired principles. Examples of such applications include modeling architectures to simulate complex adaptive systems, as in traffic planning, and biologically inspired immune systems for computers. Other areas of research are driven by theoretical questions about the nature of emergence, the origin of life, and forms of self-organization, growth, and complexity.

The media of artificial life

Artificial life may be labeled *software, hardware,* or *wetware,* depending on the type of media researchers work with.

Software. Software artificial life is rooted in computer science and represents the idea that life is characterized by form, or forms of organization, rather than by its constituent material. Thus, "life" may be realized in some form (or media) other than carbon chemistry, such as in a computer's central processing unit, or in a network of computers, or as computer viruses spreading through the Internet. One can build a virtual ecosystem and let small component programs represent species of prey and predator organisms competing or cooperating for resources like food.

The difference between this type of artificial life and ordinary scientific use of computer simulations is that, with the latter, the researcher attempts to create a model of a real biological system (e.g., fish populations of the Atlantic Ocean) and to base the description upon real data and established biologic principles. The researcher tries to validate the model to make sure that it represents aspects of the real world. Conversely, an artificial life model represents biology in a more abstract sense; it is not a real system, but a virtual one, constructed for a specific purpose, such as investigating the efficiency of an evolutionary process of a Lamarckian type (based upon the inheritance of acquired characters) as opposed to Darwinian evolution (based upon natural selection among randomly produced variants). Such a biologic system may not exist anywhere in the real universe. As Langton emphasized, artificial life investigates "the biology of the possible" to remedy one of the inadequacies of traditional biology, which is bound to investigate how life actually evolved on Earth, but cannot describe the borders between possible and impossible forms of biologic processes. For example, an artificial life system might be used to determine whether it is only by historical accident that organisms on Earth have the universal genetic code that they have, or whether the code could have been different.

It has been much debated whether *virtual life* in computers is nothing but a model on a higher level of abstraction, or whether it is a form of genuine life, as some artificial life researchers maintain. In its computational version, this claim implies a form of Platonism whereby life is regarded as a radically medium-independent form of existence similar to futuristic scenarios of disembodied forms of cognition and AI that may be downloaded to robots. In this debate, classical philosophical issues about dualism, monism, materialism, and the nature of information are at stake, and there is no clear-cut demarcation between science, metaphysics, and issues of religion and ethics. If it really is possible to create genuine life "from scratch" in other media, the ethical concerns related to this research are intensified: In what sense can the human community be said to be in charge of creating life de novo by non-natural means?

Hardware. Hardware artificial life refers to small animal-like robots, usually called *animats,* that researchers build and use to study the design principles of autonomous systems or *agents*. The functionality of an agent (a collection of modules, each with its own domain of interaction or competence) is an emergent property of the intensive interaction of the system with its dynamic environment. The modules operate quasi-autonomously and are solely responsible for the sensing, modeling, computing or reasoning, and motor control that is necessary to achieve their specific competence. Direct coupling of perception to action is facilitated by the use of reasoning methods, which operate on representations that are close to the information of the sensors.

This approach states that to build a system that is intelligent it is necessary to have its representations grounded in the physical world. Representations do not need to be explicit and stable, but must be situated and "embodied." The robots are thus situated in a world; they do not deal with abstract descriptions, but with the environment that directly influences the behavior of the system. In addition, the robots have "bodies" and experience the world directly, so that their actions have an immediate feedback upon the robot's own sensations. Computer-simulated robots, on the other hand, may be "situated" in a virtual environment, but they are not embodied. Hardware artificial life has many industrial and military technological applications.

Wetware. Wetware artificial life comes closest to real biology. The scientific approach involves conducting experiments with populations of real organic macromolecules (combined in a liquid medium) in order to study their emergent self-organizing properties. An example is the artificial evolution of ribonucleic acid molecules (RNA) with specific catalytic properties. (This research may be useful in a medical context or may help shed light on the origin of life on Earth.) Research into RNA and similar scientific programs, however, often take place in the areas of molecular biology, biochemistry and combinatorial chemistry, and other carbon-based chemistries. Such wetware research does not necessarily have a commitment to the idea, often assumed by researchers in software artificial life, that life is a composed of medium-independent forms of existence.

Thus wetware artificial life is concerned with the study of self-organizing principles in "real chemistries." In theoretical biology, *autopoiesis* is a term for the specific kind of self-maintenance produced by networks of components producing their own components and the boundaries of the network in processes that resemble organizationally closed loops. Such systems have been created artificially by chemical components not known in living organisms.

Conclusion

Questions of theology are rarely discussed in artificial life research, but the very idea of a human researcher "playing God" by creating a virtual universe for doing experiments (in the computer or the test tube) with the laws of growth, development, and evolution shows that some motivation for scientific research may still be implicitly connected to religious metaphors and modes of thought.

See also ARTIFICIAL INTELLIGENCE; CYBERNETICS; CYBORG; INFORMATION TECHNOLOGY; PLAYING GOD; ROBOTICS; TECHNOLOGY

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CLAUS EMMECHE

ASTRONOMY

Astronomy is the scientific study of the objects visible in the night sky by means of telescopes and associated instruments that analyze the radiation received from these objects. Using such instruments, astronomers determine their positions, apparent motions, distances, sizes, and total radiation emitted. From their spectra (the decomposition of light received from them into wavelengths) astronomers determine their chemical composition and radial motion. Astronomy distinguishes planets from stars, and identifies the way stars are spatially associated in star clusters, galaxies, and clusters of galaxies. Astronomy has ancient roots arising from peoples' attempts to relate the annual change of seasons to positions of stars in the sky. Astronomy is to be distinguished from astrology, which purports to relate the events in human lives to positions of the planets at the time of one's birth.

See also COSMOLOGY, PHYSICAL ASPECTS

GEORGE F. R. ELLIS

ASTROPHYSICS

Astrophysics is the analysis of the physical structure and evolution of objects studied by means of astronomical observations (e.g., stars, galaxies, radio sources, X-ray sources, quasi-stellar objects). The physical structure of such objects depends on a balance of gravitation, radiation pressure, and centrifugal forces, while their evolution depends on their initial composition and the reactions that take place between matter and radiation. In particular, nuclear reactions create new elements in the interior of stars and provide their major energy source. Detailed analysis discloses important relations between the color of light emitted by a star and its total radiation output; this relation changes with the age of the star. At its life's end, a star may die in a supernova explosion, or it may end up as a white dwarf star, neutron star, or black hole, depending on its mass.

See also ASTRONOMY; BLACK HOLE; COSMOLOGY, PHYSICAL ASPECTS; GRAVITATION

GEORGE F. R. ELLIS

ATHEISM

Atheism, a term that began to appear with frequency only in modern times, literally means the denial of *theism,* that is, belief in the existence of a personal God who creates the world and exists independently of it. This denial may be formal and explicit, as in the writings of Karl Marx (1818–1883), Friedrich Nietzsche (1844–1900), Sigmund Freud (1856–1939), and Jean-Paul Sartre (1905–1980); or it may be an implicit "practical" atheism in which a person or community tacitly assumes that nothing transcends, or exists beyond, the physical universe. In both cases the justification for atheism is usually rooted in the alleged absence of positive evidence for God's existence. Often vaguely referred to as "unbelief," atheism comes in many varieties, but it is those forms that emphasize the lack of "evidence" for God that are of special interest in discussions of science and religion.

Atheism also arises, of course, among those who consider it impossible logically to reconcile the idea of an all-powerful and omnibenevolent God with the fact of evil and suffering in the world. The physicist and Nobel laureate Steven Weinberg (1933–), for example, has stated that it is not only the absence of evidence but, even more, the fact of evil and suffering that grounds his own atheism. Along with many others today, he finds in the suffering of living beings, especially as this has been exposed by evolutionary biology, a stronger reason for rejecting theism than the mere absence of physical evidence warrants. Since the days of Charles Darwin (1809–1882) the indifference of natural selection to the pain and the extinction of sentient organisms has often been cited as a clinching scientific reason for atheism. Darwin himself was unable to reconcile the idea of an intelligent divine designer with the disturbing life-struggle that his own evolutionary science uncovered. And among scientists today it is more often biologists than physical scientists who reject the notion of a personal God.

It should be noted, however, that the renunciation of theism because of innocent suffering has been a strong temptation quite apart from any specifically scientific information given by evolutionary biology. Darwinian depictions of life may add support to an atheism already based on a compassionate protest against suffering, but the question of how to hold together the idea of God and the fact of suffering is as old as theism itself. Indeed, belief in God arose in the first place, in part at least, as a response to the fact of suffering; and biblical as well as other religious portraits of ultimate reality find in God a compassionate will to conquer suffering and death.

Consequently, as far as the question of science and religion is concerned, atheism is of interest primarily when its proponents accuse theism of failing to provide adequate evidence for its claims. Here *evidence* means empirically available and publicly accessible data that might reasonably confirm theistic claims. To many scientific thinkers such evidence is ambiguous at best and completely lacking at worst. Although the sixteenth- and seventeenth-century founders of modern science (Nicolaus Copernicus, Francis Bacon, René Descartes, Galileo Galilei, Isaac Newton, Robert Boyle, and others) were convinced theists, there is little question that they ironically bequeathed to Western intellectual culture, and especially to modern philosophy, an understanding of truth-seeking (or an epistemic method) that has led many educated people to be skeptical of all propositions unsupported by experimental evidence. And since it is the very nature of theism to refer to a deity that is sensually unavailable, or to propose that believers wait patiently in unconditional trust for a future revelation of indisputable evidence of the divine, the idea of God seems especially uncongenial to confirmation by scientific method.

To those who elevate scientific method to the status of sole or primary arbiter of truth, therefore, all references to a hidden personal deity will be suspect. In the absence of empirical evidence, they ask, how can scientifically educated people be expected to take seriously theistic beliefs about the creation of the world, the eternal love of God, or the ultimate purpose of the universe? The renowned British philosopher Antony Flew (1923–), applying Karl Popper's (1902–1994) criterion of falsifiability to the question of God's existence, has argued that since no counter-evidence would ever be enough to uproot the beliefs of a confirmed theist, theism violates the (scientifically shaped) rules of rational inquiry. If God lies beyond the domain of possible empirical verification or falsification, the claim goes, then theism cannot pass the most elementary test for truth.

At times the demand for theists to provide empirical evidence of God's existence is framed as a moral requirement, any violation of which is held to be indicative not only of cowardice but also of unethical insensitivity to the value of truth. The famous French biochemist and professed atheist Jacques Monod (1910–1976), for example, sought to base all of culture on what he called the postulate of (scientific) objectivity, which for him constituted the core of a new ethic of knowledge being ushered in by the modern age of science. Accordingly he dismissed theistic affirmations and all religious hope for final redemption as instances not only of cognitive but also moral delinquency. An earlier example of such passionate commitment to an "ethic of knowledge" is that of the American philosopher W. K. Clifford (1845–1879), whose essay "The Ethics of Belief" (1879) became famous in William James's (1842–1910) criticism of it in the "The Will to Believe." Clifford had stated that "it is wrong always, everywhere, and for anyone to believe anything upon insufficient evidence" (p. 183), an assertion that James along with others chastised for its puritanical extremism. In any case, among the beliefs for which sufficient evidence is especially lacking, at least according to Clifford's standards, are those of theists.

Does science support atheism?

The important question, then, is whether science, or the "scientific spirit," provides an incontestable basis for atheism. Although many atheists claim that it does, strictly speaking science as such can in principle justify neither atheism nor theism. By definition scientific method places theological interests beyond the compass of its concerns. Science does not as such ask about values, meaning, or God. Consequently the assertion that science sanctions atheism is logically spurious. Such a claim emanates not from science but from *scientism,* the belief that science is the only road to reliable knowledge. But one may legitimately ask whether this particular belief (scientism) orients the human mind reliably to the fullness of being or truth. Since it is impossible to conceive of an experimental situation that could in principle confirm or falsify the belief that science is the sole avenue to truth, it may be argued that scientism is a self-refuting proposition.

Nevertheless, it is undeniable that the progress of modern science has been accompanied historically by a rising skepticism, especially in the intellectual world, about the existence of a personal God. To many scientific thinkers the decline of theistic religion in modern times, especially among educated people, is a logical and not simply historical correlate of the advance of science. Albert Einstein (1879–1955), for example, famously asserted that the existence of a personal God, one capable of miraculously intervening in nature or history, would be incompatible with a basic assumption of all modern science, namely, that the laws of nature are utterly inviolable and invariant. For a scientist to believe in a responsive, personal God, a God who answers prayers, would be inconsistent with the very essence of scientific inquiry, which can tolerate no exceptions to natural laws.

Einstein, however, did not accept the label of "atheist" since it seemed a term of opprobrium and one that during his lifetime often implied moral relativism, which he vehemently opposed. Moreover, as a disciple of the famous Dutch pantheist Baruch Spinoza (1632–1677), he was not opposed to using the term *God* to refer to the mystery of "intelligence" that pervades the universe and makes possible the whole enterprise of scientific exploration. Einstein considered himself a deeply religious man, provided that "religion" is taken to mean a firm commitment to universal values (goodness, beauty, truth) and a cultivation of the insurmountable "mystery" encompassing the universe. But he considered the idea of a personal God dispensable to living religion.

Responding to Einstein, theologian Paul Tillich (1886–1965) insisted that living religion cannot dispense with the idea of a personal God since an impersonal deity would be lower in being than persons are. God must be "at least personal" in order to evoke the attitude of religious worship. God is much more than personal, of course, and so theology must acknowledge that personality is one among many symbols that religion employs in its attempts to understand ultimate reality; but it is not optional to theism. Addressing the objection by scientific atheists that God does not fall among the objects of empirical investigation, Tillich replied that God by definition cannot be one "object" among others—even if the most exalted of these—without ceasing thereby to be God. If God is to be taken as the deepest reality it would be as the "ground of being" rather than as one being among others. Religious awareness of such a reality, however, comes not by grasping it empirically or scientifically, but only by allowing oneself to be grasped by it.

See also EVIL AND SUFFERING; FALSIFIABILITY; THEISM

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JOHN HAUGHT

ATOMISM

Atomism (from Greek *átomos:* indivisible) considers every substance (including living beings) to be made up of indivisible and extremely small material particles, the *atoms*. Every sensual quality of perceptible bodies has to be explained by the qualities, configurations, and changes of the atoms composing it, so that the (secondary) qualities of a compound are completely determined by and reducible to the (primary) qualities of its component atoms.

Historically, atomism can be traced back to antiquity, namely to the pre-Socratic philosophers of nature, Leucippus (born c. 480/470 B.C.E.) and Democritus (c. 460–370 B.C.E.). Due to Aristotle's convincing arguments against atomism, and because of its materialistic and atheistic worldview, it was unimportant during the Middle Ages. It was only with the seventeenth century that atomism was transformed into a scientific theory. Pierre Gassendi (1592–1655) revived classical atomism and explained the physical world as being constituted by finitely many atoms, which move in a void and have been endowed by God with a conserving momentum, thus freeing atomism from the stigma of being atheistic. Gassendi already allowed atoms to form compounds, which he called *moleculae* or *corpuscula*. The eighteenth and nineteenth centuries then gave rise to chemical atomism, which distinguished element from compound. Although Isaac Newton (1642–1727) had already speculated in detail on the atomic nature of matter and light in his *Opticks* (1704), physical atomism became widely accepted only after the development of the kinetic theory of gases in the nineteenth century. Atomism strongly supported the deterministic worldview of classical mechanics.

With the discovery of the electron and of radioactive decay, atoms themselves were recognized as composites and not indivisible units. The first atomic models were constructed in analogy to a macroscopic planetary system obeying classical laws of motion (negative electrons circling around a nucleus of neutrons and positively charged protons), but these models proved to be inconsistent. Erwin Schrödinger (1887–1961) and others then applied quantum mechanics to the atom. They substituted the electron orbits with probability distributions (*orbitals*), which indicate in which regions of space the electron is most likely to be found. The transition from one state of the atom to another also follows quantum principles, which imply fundamental uncertainties. It has also been shown that two quantum objects that interacted once stay correlated in some of their properties, even if they move away from each other (*EPR effect*). Thus, modern atomism with its dynamic view of matter has overcome the mechanistic tendencies of classical atomism and presents material reality as a holistic, fluctuating, and not fully determined net of coherence, which cannot be reconstructed as a set of completely separable massive objects that follow determined trajectories. Consequently, Alfred North Whitehead (1861–1947) suggested that processes ("actual entities") rather than substances are "the final real things of which the world is made up" (Whitehead, p. 18).

Thus, contemporary atomism opens new perspectives for the dialogue between science and religion, insofar as nature can be envisioned as being open for divine and human creative action. Living beings, human values, the act of striving for meaning and fulfillment in life, religious beliefs, and science itself are not mere agglomerations and idle enterprises in a mechanical world of swirling atoms, but can be understood as emergent and meaningful phenomena in an evolving process of creation.

See also EPR PARADOX; MATERIALISM

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DIRK EVERS

ATTRACTOR

Attractor is a technical term in the theory of dynamic systems. An attractor can be defined as a part of the phase space of a dynamic system to which the system confines itself in the course of time, until it is trapped in it. The simplest example of an attractor is the point of rest of a pendulum, which is geometrically represented by a simple point. More complicated dynamic systems have attractors that require complicated geometric representations. *Strange attractors,* the attractors of chaotic dynamic systems, have fractal geometric representations.

See also CHAOS THEORY

WOLFGANG ACHTNER

AUGUSTINE

Augustine (354–430 C.E.) was born on November 13 in Thagaste in present-day Algeria. His father Patricius, a town councilor with a modest income, was a pagan who was only baptized on his deathbed. Patricius was married to a Christian woman named Monnica, with whom he had three children.

As a young man, Augustine studied grammar and rhetoric in Madaura. Owing to the limited financial means of his family, he was obliged to return home when he was sixteen. Thanks to help from friends, however, he was able to travel to Carthage, where he completed his studies. At the age of eighteen he read Cicero's *Hortensius,* which impressed him and awakened in him a desire for wisdom. He was disappointed with his first reading of the Scriptures, however, largely because of what he deemed to be their inferior literary quality. He turned to the Manichaeans for the next nine or ten years, attracted by their promise of knowledge without faith. Around 372 he met a woman, with whom he would live for thirteen years and with whom he would have a son, Adeodatus. To earn a living, he taught rhetoric in Carthage, but he was disappointed in his students, who apparently were far from attentive and did everything to disrupt the classes. In 383, he left Carthage and traveled to Rome but was similarly dismayed when his students there failed to pay for their lessons. He then traveled to Milan, at that time the capital of the Roman Empire in the West, where his Manichaean friends and the prefect of Milan, Symmachus, secured for him a post as a teacher of rhetoric.

While in Milan, Augustine heard sermons by Ambrose, the bishop of Milan, whose stylish appearance and impressive performance profoundly impressed Augustine. Disappointed by the Manichaeans' failure to deliver the promised insight, Augustine decided to leave the movement, and for a short time he leaned toward skepticism because he thought he would never gain the truth he desired.

In Milan he was joined by his mother, who sent away Augustine's mistress and sought a fitting wife for him. Adeodatus remained with his father. The matchmaking efforts failed, however, when Augustine came under the influence of Platonism, in part due to the strong Platonic bias of Ambrose's sermons. In Platonic thought, Augustine found an answer to the then existential question: *unde malum* (Where does evil come from?). His inability to renounce physical desire delayed his conversion until the autumn of 386. But after reading Romans 13:13–14 he became convinced of the need to renounce "worldly depravity," and on Easter night 387 he received baptism. He thereafter decided to return to Africa but was forced to wait until 388 because of the political turmoil. A revolt of the Roman troops in Africa postponed his return.

Augustine founded a religious community in Thagaste, where he spent his time in study and writing, and soon became a respected scholar. He traveled to nearby Hippo in 391, where he was persuaded to become a priest and to assist Valerius, the bishop of Hippo. Augustine succeeded Valerius as bishop in 395 or 396, a role he fulfilled with great dedication for the rest of his life. He also served as pastor in the liturgy and as a judge, and he took great care in attending to people's material needs. Letters discovered in 1975 (first critical edition: 1981) reveal his profound concern for the condition and well-being of the poor and the slaves. Augustine also worked to refute the Manichaeans, and he was involved in discussions with the Donatists, a local Christian movement, which actively opposed Roman oppression.

Around 411, Augustine decided to address Pelagianism, a strong ascetically oriented movement, which Augustine felt put too little emphasis on God's saving grace in Jesus Christ and depended too heavily on the moral potential of human beings themselves. Augustine's dispute with the Pelagians lasted until the end of his life. Especially in his last works, which were destined to be read by monks in Hadrumetum and Marseille, Augustine emphasized predestination, creating the impression that he had given up on the capacity of the human will. Because of this, and also because of his negative opinion of *concupiscentia carnis* (sinful desire, mainly in its sexual manifestation), scholars assess this period of his life to have been pessimistic.

Works

Augustine was the most productive author in Latin antiquity. His autobiographical *Confessions* describes his life up to his conversion. This work and Augustine's *De civitate Dei* (*City of God*), written after the fall of Rome in 410, have become classics of world literature. Because of his intellectual prestige, he was asked to offer his views on a wide range of matters. In addition to *Confessions* and *De civitate Dei,* his most important works are *Enarrationes in Psalmos* (Explanations of the Psalms c. 418), *De Trinitate* (The Trinity c. 420), and *Enchiridion* (A Handbook on Faith, Hope, and Love 422). His late works form part of the basis for the theological developments of the Reformation and the Jansenism movement during the sixteenth and seventeenth centuries.

Views on science and religion

The correlation between faith and reason arose during Augustine's time, and his thinking was influenced by such trends as Stoicism, neo-Platonism, and Manichaeism. He was, of course, greatly influenced by the Scriptures and the writings of his Christian predecessors. The Scriptures represented ultimate authority and the source of all truth for Augustine. His reflections on the relation between faith, knowledge, and "science" developed within his theocratic image of the world and humankind. For Augustine, the one and only (Jewish-Christian) God is the creator of the universe and humankind (body and soul). Humans, like all parts of nature, are dependent on the creator. Such a view involves an inherent teleology, toward which the universe as process is ultimately ordered (*Confessions* 9, 23, 24). It also means that true knowledge is dependent on having a correct relationship with a personal and provident God, a view that deviates from the classical philosophy of, for example, the Stoa, where the cosmos as a whole represents a living and rational reality. According to Augustine, humans look for knowledge of self and God through reason because this will provide them with true happiness; religion cannot be disconnected from an active pursuit of truth. Religion and truth are closely bound, and knowledge occurs by means of an inward upward movement in the course of which truth reveals itself. For Augustine, one must search for truth in one's heart, and this inward movement must lead to a transcendent movement toward God, the truth. In this process God, who is love, plays an essential role because knowledge and love are bound together: As Augustine states in *De Trinitate* (9, 2, 2), "There is no knowing without loving, and no loving without knowing." For Augustine, body and soul are also closely linked, and Augustine's reflections on body and soul helped form the basis of the Western concept of "self." Furthermore, human freedom and autonomy for Augustine do not have the same importance as they enjoy in modern thought. Philosophy, psychology, anthropology, and theology are always intrinsically linked and cannot be separated. Augustine's view of human history is essentially determined by his belief in the God of Jesus Christ and in the crucial part that Christ, as sole intermediary, plays in history. Augustine was convinced that there can be no true knowledge, salvation, or welfare outside of faith in Christ. The only criterion of judgment is the Christian faith.

The soul must guide the body and serve as reference to God; it is the image and likeness of God, which is why human beings, of all creatures, are closest to God. The soul hosts the memory and makes humans rational beings. Augustine distinguishes between superior reason (also called *intellectus* and *sapientia*), which is concerned with knowledge of unchanging principles, and inferior reason, which is focused on temporary things and is related to science. It is via superior reason that humans can see the truth "in" God.

Augustine is less univocal in his discussion of the body, which he judges in both positive and negative terms. He often spoke of love for the body and the duty to take care of it. When reacting to Manichaean dualism, he emphasized that the body is an essential part of the human person, and he strongly defended the resurrection of the body. At the same time, he regarded the body as a hindrance to the soul in the search for true happiness and as a source of sinfulness and mortality. In this connection he often spoke in a Pauline sense about life according to the flesh, in which the soul itself is always actively involved. Especially during the Pelagian controversy, Augustine emphasized that there is a sinful longing in all people (*concupiscentia carnis*), which prevents them from doing the good they want to do.

Augustine's life can be described as a continuous search for the truth, although he was not a scientific theologian in the medieval or modern meaning of the word. Especially in his early period, he looked for mathematical (positive-scientific) certainty in his search for truth, which helps explain his interest in astrology. Augustine quickly discovered, however, that astrology did not lead him to the truth he sought, and his initial sympathy would, after a period of skeptical doubt, disappear. Around 400, he rejected the power of astronomy to predict people's fate on the basis of heavenly signs. He thereafter fiercely and repeatedly criticized astrology, although Bernard Bruning has suggested that Augustine may have traded his initial astrological fatalism for a divine fatalism (predestination). Nonetheless, after his conversion Augustine became convinced that true knowledge could only be gained through Christian revelation, even though this knowledge would always remain fragmentary and incomplete in this world.

See also EMBODIMENT; FAITH; FREEDOM; GOD; IMAGO DEI; REVELATION; SOUL; TELEOLOGY

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MATHIJS LAMBERIGTS

AUTOMATA, CELLULAR

A cellular automata (CA) is a network of connected, identical, finite state automata, which are typically arranged in a one-, two-, or three-dimensional grid, where each grid cell corresponds to one automaton. A *finite state automaton* is a simple mathematical model for processes that can be described by a table of state transitions and limited memory, which only allows immediate calculations without delays. Each automaton has a state and a set of program rules defined in the state transition table. The state transitions are defined as a function of the current state and the state of its neighbors according to the program rules. Time and space in CAs are discrete—that is, they are represented as discrete time steps and a finite number of cells respectively. During runtime, the state of all automata is updated between time step t and $t + 1$ based on the states of all automata at time t, resulting in synchronized state transitions.

The neighbors of each automaton are defined by a neighborhood topology, typically (but not necessarily) specified as the immediate neighboring cells. In the case of the most common two-dimensional grids with square cells, these are often five (center, right, left, above, below) and nine (the five neighborhood and all diagonals) cell neighborhoods. Often CAs are also defined as discrete dynamic systems in contrast to differential equations that describe continuous dynamic systems.

CAs were introduced by computer pioneers John von Neumann (1903–1957) and Stanislaw Ulam (1909–1984) in the 1940s. The original work was published in the 1966 by A.W. Burks. The motivation for this approach was to propose a formal framework to model the dynamics of complex systems by means of repeated local interactions between simple components. In this context, von Neumann wanted to investigate what kind of logical organization of an automaton is sufficiently powerful to produce the self-organization principles found in nature. For this purpose he proposed a CA model with twenty-nine states and a five neighborhood, which has universal computation capabilities—it is powerful enough to calculate any computable task equivalent to a Turing machine.

An important instance of CA is the "game of life," which was introduced by mathematician John H. Conway in 1970. The game of life is a CA that consists of a two-dimensional grid of square cells with a nine neighborhood where each cell (automaton) has just the two states "alive" and "dead." Cells die if they have less than two or more than three live neighbors and become alive if they have exactly three live neighbors. It has been shown that Conway's very simple CA resembles a universal computer. The game of life is capable of producing complex organizational patterns, which, depending on the initial states of the cells, can be static, periodically changing, or moving. Interestingly, the size versus the frequency of state transitions in the game of life follows a power law relationship, which is a typical phenomenon found among a great variety of complex systems, which are in a state between stability and chaos called *self-organized criticality.* So far no other instance of cellular automata has been found that expresses the same property.

Cellular automata have been mainly investigated in artificial life and complexity science, but have also gained importance in other fields. In biology, CAs serve as simple frameworks for modeling the spatial effects of the interactions between neighbored individuals. In particular, CAs have been used to model space in game theory for various research issues, including the evolution of cooperation.

See also COMPLEXITY; EVOLUTIONARY ALGORITHMS; SELF-ORGANIZATION

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THIEMO KRINK

AUTOPOIESIS

The modern concept of autopoiesis emerged within biological discourse, was picked up in sociology, and is increasingly present in debates within the philosophy of science. With ontological as well as epistemological implications, it touches religious understandings of God's action in the world and images of the original as well as ongoing creation. It promises to bridge natural and cultural processes.

While the problem itself was already described in the late eighteenth century by the German philosopher Immanuel Kant (1724–1804), the term *autopoiesis* was coined in the 1970s by the Chilean theoretical biologists Humberto Maturana and Francisco J. Varela in order to denote the operative closure of living systems and their ability to produce themselves. Any cell that, by means of molecular processes, reproduces its own building blocks on which it at the same time depends, operates on an autopoietical basis. These molecular elements are part of a complex network of components, which is on the one side constantly reproduced and maintained, and on the other side simultaneously the very basis of this operation.

As a result of this autonomy and operative closure, autopoietic systems lack any immediate contact with their environment even though they are energetically open systems and are forced to produce "order from noise" within this environment. In this regard, the theory of autopoietic systems replaces older ideas of a causal input and output across the border of systems, as well as stimulus/response models.

In reacting to their own inner states, autopoietic systems are self-determined. They are not independent of their environment, but if they respond to it they do it in a nondeterminate way. The environment can only stimulate system-specific processes and states. In epistemological contexts this opens up the possibility of developing an empirical theory of knowledge, which relativizes widespread ontological presuppositions since "reality" is the product of inner-systemic processes of the observer. On the other hand, autopoietic theories also suggest an ontology of multiple autonomous *and* interdependent levels of reality.

While Varela wants to restrict the concept of autopoiesis to cell systems, immune systems, and nerve systems, Maturana has extended it to human societies and epistemological issues, thereby providing support for radical constructivism. The German sociologist Niklas Luhmann (1927–1998) introduced the concept into the social sciences in order to characterize the self-referential operative closure of social systems and psychic systems. Social systems consist of communication, and psychic systems of thoughts. Neither can reach into their environment, but are open to it because of their self-referential closure.

The concept of autopoiesis has been criticized by some Christian theologians because it challenges not only the idea of a teleology immanent to nature but also the notion of total passivity and dependency in creation theology. It seems to replace the very idea of a *creatio ex nihilo*.

However, the concept was constructively used by Niels H. Gregersen in order to overcome the breach between God's activity and the self-productivity of God's own creatures. By distinguishing self-constitution in the sense of a theological ultimate beginning (creation *de novo*) from constituted autopoiesis as ongoing self-creative creativity based on self-constitution, Gregersen describes God as being creative by supporting and stimulating autopoietic processes. Autopoiesis can illuminate the theological notion of God's continuous creation, of providence in nature, and particularly of God's blessing. Within this context of creation the notion of autopoiesis resonates with God's self-giving nature and with the Christian notion of God's internal trinitarian self-realization.

See also CONSTRUCTIVISM; CREATIO CONTINUA; CREATIO EX NIHILO; DIVINE ACTION; PROVIDENCE; SELF-ORGANIZATION

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GÜNTER THOMAS

AVERROËS

The Aristotleanism of Ibn Rushd (Averroës), combined with his thorough training in various aspects of Islamic scientific and philosophical traditions, contributed to the evolution of his discourse on the relationship between science and religion. He lived at a moment in time particularly suited to synthesizing a broad understanding of philosophy and the philosophical sciences in which religion had a central position. Ibn Rushd's dialectical treatment of the role of religion and philosophy in human affairs and his theory of knowledge remain relevant to the contemporary science and religion discourse.

Life and writings

Averroës, whose real name was Abu'l Walid Muhammad ibn Ahmad ibn Muhammad ibn Rushd, was an Arab philosopher known as "The Commentator" to the medieval West because of his commentaries on Aristotle. Ibn Rushd was born in Córdoba, Spain, in 1126 C.E. to an eminent family of jurists. His grandfather had been a *Qadi* (judge) and *Imam* (Muslim leader of the congregational prayers) of the mosque of Córdoba. Ibn Rushd's early education was in the traditional pattern of Islamic education. He studied Arabic, the Qur'an, traditions of the Prophet and, later, natural sciences.

In 1153, Ibn Rushd traveled to Marrakash in Morocco where he helped the Almohad ruler 'Abd al-Mu'min to establish colleges. In 1169 or slightly earlier, Ibn Rushd was introduced to the learned prince Abu Yaqub Yusuf by the philosopher Ibn Tufayl. When Abu Yaqub succeeded 'Abd al-Mu'min, Ibn Rushd found great favor with him throughout his rule (1163–1184). Ibn Rushd was made the Qadi of Seville in 1169. Two years later, he returned to his favorite Córdoba as Qadi. He traveled to various parts of the country, including longer sojourns in Seville, from where he dates several of his works between 1169 and 1179. In 1182, while in Marakash, Ibn Rushd succeeded Ibn Tufayl as the chief physician to Abu Yaqub Yusuf. Ibn Rushd remained in favor during the reign of Abu Yaqub's successor, Yaqub al-Mansur, except for a short period when his rivals were able to convince the ruler that his philosophical works were against the teachings of Islam. But al-Mansur called him back to his court as soon as he moved to Marrakash, where Ibn Rushd died in1198. He was buried in Marrakash outside the gate of Taghzut but later his body was taken to Córdoba where the young mystic Ibn 'Arabi was present at his funeral.

Ibn Rushd's commentaries on Aristotle can be divided into short (*jawami'*), middle (*talkhis*) and great (*tafsir*); the first two types were written between 1169 and 1178. His greatest medical work, the *Colliget* (*al-Kulliyyat,* Book of generalities)*,* also belongs to this period. He wrote most of his original works between 1174 to 1180. These include *Kitab al-'aql* (Treatises on the intellect), *De substantia orbis* (Nature of heavens), *Fasl al-maqal* (The Decisive chapter)*, Kashf al-manahij al-adillah* (Discovery of the methods of proof), and *Tahfut al-Tahafut* (Incoherence of the incoherence).

Philosophy

Ibn Rushd's philosophy was strongly influenced by his training in the principles of jurisprudence (*Usul*) on the one hand and by Aristotle and certain Muslim philosophers (*falasifa*), especially al-Farabi, Ibn Bajja and Ibn Tufayl, on the other hand. He criticized Ibn Sina's (Avicenna) philosophy but respected his medical works (indeed, he wrote a commentary on Ibn Sina's medical poem, *al-Urjuza fi'l tibb* [Recompense for medicine]). Ibn Rushd's relationship with Ibn Tufayl was one of deep respect for the elder philosopher who was also his mentor. But while Ibn Tufayl was mystically inclined, Ibn Rushd was not. The two philosophers recognized the convergence of philosophy and revelation but whereas Ibn Tufayl leads Absal, the second main character of his celebrated narrative *Hayy ibn Yaqzan* (The Living son of the awake), to a mystic vision of knowledge, Ibn Rushd remains strictly within the philosophical realm.

In his *Fasl al-makal wa-takrib ma bayn al-sharia' wa'l hikma min al-ittisal* (Authoritative treatise and exposition of the convergence of religious law and philosophy), written before 1179, Ibn Rushd formulated a conception of philosophy that was in accordance with the Qur'anic teachings. For him, philosophy was a rational view of creation that leads to the knowledge of the creator. Thus formulated, philosophy becomes a valid path for discovery of truth, which is also to be found in revealed texts. Because different individuals have different levels of comprehension, God speaks to humans through three kinds of discourses: dialectical *(al-aqawil al-jadaliyya);* rhetorical *(al-aqawil al-khitabiyya)* and demonstrative syllogism *(al-aqawil al-burhanniyah).* This validation of philosophy led Ibn Rushd to formulate his theory of knowledge, in which the findings of rational research are collaborated with the revealed text through a reinterpretation of the text in accordance with the established rules of the Arabic language. This interpretation *(Ta'wil),* Ibn Rushd points out, is in accordance with the Qur'an because the Qur'an itself distinguishes between those verses that have fixed and clear meanings *(ayat al-muhkamat)* and those that are open to several interpretations *(ayat al-mutashabihat).*

Ibn Rushd cherished the honor given to scholars by the Qur'an and used this to demonstrate that scholars have the right to interpret those verses that lend themselves to rational speculation, but such interpretation, he held, should remain in the scholarly circles; it should not be passed on to the common folk who do not have the capacity to understand it. He criticized Muslim philosopher al-Ghazali for not following this rule. This criticism is present in many works of Ibn Rushd, in various forms and degrees, but it is in his master piece, *Tahafut al-Tahafut* (The Incoherence of the incoherence), that he forcefully attacks not only al-Ghazali but also all those neo-Platonic philosophers who had distorted Aristotle's teachings, including Ibn Sina and his followers.

Tahafut al-Tahafut deals with some of the basic problems of philosophy and it reconstructs

Ibn Rushd's conclusive ideas about time, eternity, creation, divine action, causality, and other fundamental issues. Using al-Ghazali's *Tahafut al-Falasifa* (Incoherence of the Philosophers) as the lynchpin for his attack, Ibn Rushd attempts to prove the eternity of the world. Ibn Rushd rejects the emanationist doctrine that the "One" can give birth only to one. He also criticizes Ibn Sina's notion of "Necessary Being" on the grounds that it is not possible to separate essence and existence; the distinction is made only in thought. Ibn Rushd's God is conceived as the One who is part of the universe. Unlike Ibn Sina for whom God is transcendent and is situated beyond the moving intelligences, divinity is the cause of the physical order for Ibn Rushd. Thus Ibn Rushd conceives God in purely Qur'anic terms, but through Aristotelian method. He refuses to separate divinity from its attributes. It is only human thinking that distinguishes between the two according to what people consider to be one or another of the infinite divine perfections.

Influence

Ibn Rushd's influence on the Western scholars is well known. In canto four of the *Inferno,* Dante called him "*che'l gran comento*" (the great commentator) and gave him the place of honor along with Euclid, Ptolemy, Hippocrates, Avicenna, and Galen. In Europe, the University of Padua became the main center of Averroism, though the Universities of Paris and Bologna were not far behind. But it is his masterly and clear exposition of Aristotelian thought that earned Ibn Rushd the title of "The Commentator," not his original ideas. His originality was, in fact, belittled by nineteenth-century French philosopher Ernest Renan and those who followed him. However, a more correct appreciation of Ibn Rushd is slowly emerging.

See also ARISTOTLE; AVICENNA; ISLAM; ISLAM, CONTEMPORARY ISSUES IN SCIENCE AND RELIGION; ISLAM, HISTORY OF SCIENCE AND RELIGION

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MUZAFFAR IQBAL

AVICENNA

In spite of the enormous difference between the science of his day and contemporary science, Ibn Sina (Avicenna) remains an essential link in the science and religion discourse. This is so because Ibn Sina addressed some of the most fundamental questions regarding the relationship between science and religion: How did the cosmos come into existence?; What is the role of God in the unfolding of human and cosmic destinies?; How does God interact with created beings? These and many other questions critical to contemporary discussions occupy a central position in Ibn Sina's philosophy, if not his science.

Life and writings

Abu'l'Ali al-Husayn Ibn 'Abd Allah Ibn Sina, whose name was Latinized as Avicenna during the Middle Ages, is known in the Muslim world as Ibn Sina. He was one of the most important representatives of the encyclopedic tradition of learning that was the hallmark of Islamic scholarship. Honorifically called *al-Shaykh al-Ra'is (*the Grand Shaykh), Ibn Sina was born in 980 C.E. in Afshana, his mother's home town near present-day Bukhara, Uzbekistan, during the reign of Amir Nuh ibn Mansur al-Samani.

We know about his life and works from two authoritative sources: an autobiography that covers the first thirty years of his life and a detailed life-sketch left behind by his disciple and friend al-Juzjani. Ibn Sina's father was a high official of the Samanid administration. His native language was Persian and he was first educated at home and then sent to learn jurisprudence from Isma'il al-Zahid. He studied Ptolemy's *Almagest,* Euclid's *Elements,* and logic with the famous mathematician Abu 'Abdallah al-Natili. By the time of his sixteenth birthday, Ibn Sina had mastered physics, medicine, metaphysics, and he was well-known as a physician. During the next two years, he was able to master Aristotle's metaphysics with the help of al-Farabi's commentary.

The first important turning point in the life of Ibn Sina came in the year 997 when, as a physician, he successfully treated the ruler of Bukhara, Nuh ibn Mansur; this opened the doors of one of the best libraries of its time to the young Ibn Sina. He spent the next several months in the palace library and saturated his mind with the best of medieval learning to such an extent that many years later he remarked to his disciple Juzjani, "I now know the same amount as then but more maturely and deeply; otherwise the truth of learning and knowledge is the same."

The earliest of Ibn Sina's surviving works date from 1001 when he was twenty-one; these include the twenty-volume *Kitab al-hasil wa'l-mahsul* (Book of sum and substance) dealing with all sciences, *Kitab al-majmu'* (Book of compilation) on mathematics, and *Kitab al-birr wa'l- ithm* (Book of virtue and sin) on ethics.

The second important turning point in Ibn Sina's life can be traced back to the year 1002 when his father died amidst political turmoil and war, and Ibn Sina left Bukhara for Jurjaniyah, then the capital of the Khwarazmian dynasty, where he found patronage in the court of the ruler, Abu'l Hasan Ahmad ibn Muhammad al-Suhaili. It was for al-Suhaili that Ibn Sina wrote two treatises on mathematics and astronomy, *Kitab al-tadarik li anwa' al-khata fi'l tadbir* (Book of remedy for mistaken planetary positions) and *Qiyam al-ard fi wasat al-sama'* (The Establishment of earth in the middle of the sky). But Ibn Sina had to flee again because of political turmoil. He set out for Jurjan because of the reputation of its ruler as a lover of learning but when Ibn Sina arrived in the kingdom of Qabus in 1012, he discovered that the ruler had died. After ten years of moving from place to place, Ibn Sina finally settled in Ispahan in present day Iran, where he composed his masterpieces during a fifteen-year period of calm and peace. When Masud of Ghaza attacked Ispahan, this peace came to end, and Ibn Sina returned to Hamadan where he died of colic during the month of Ramadan in the year 1037.

Ibn Sina's surviving works include more than two hundred and fifty books, treatises, and letters on philosophy, cosmology, medicine, and religion. The most important among these are the voluminous *Kitab al-Shifa'* (Book of healing), *Kitaba al-Najat* (Book of salvation), *Danishnama-yi 'ala'I* (Divine wisdom), *'Uyun al-Hikmah, al-Isharat wa'l tanbihat* (Remarks and admonitions), and the famous *al-Qanun fi'l-tibb* (The Canon of medicine).

Philosophy

Ibn Sina's philosophy is based on an ontological foundation in which God, the Necessary Being *(wajib al-wujud),* is the only being that is pure goodness, the source of all existence. Everything else derives its being *(mahiyya)* and its existence *(wujud)* from the Necessary Being and hence is contingent upon God. The contingent beings *(mumkin al-wujud)* are then divided into two kinds: (1) Those that are necessary in the sense that they cannot "not be"; they are contingent by themselves but receive from the First Cause the quality of being necessary. These beings are the simple substances *(mujarradat).* And (2) those beings that are only contingent, the composed bodies of the sublunary world that come into being and pass away. Ibn Sina's importance is based on the fact that he attempted to integrate Greek philosophy and Islam in an original synthesis that places God at the center of a philosophy that is essentially based on self-evident truths. According to Ibn Sina, the idea of "being" is so rooted in the human mind that it could be perceived outside of the sensible, though the first certitude apprehended by the human mind is the one that comes by means of sense perception.

In a prefiguration of the Cartesian *Cogito ergo sum* (I think, therefore I am), Ibn Sina based his philosophy on intuition *(hads)* and on the notion that the human soul is independent of body, and hence capable of apprehending itself directly. According to Ibn Sina, the Necessary Being produces a single Intelligence (because from the One can only come one). This Intelligence possesses a duality of being and knowledge; it introduces multiplicity into the world; from it can derive another Intelligence, a celestial soul, and a celestial body.

Then, according to Ptolemy's system, this creative emanation descends from sphere to sphere as far as a tenth pure Intelligence, which governs our terrestrial world; this terrestrial world is unlike the other worlds because it is made of corruptible matter. This multiplicity surpasses human knowledge but is perfectly possessed and dominated by the active Intelligence, the tenth Intelligence. Ibn Sina demonstrated this in a highly original poetic narration, *Hayy ibn Yakzan* (The living, the son of the Awakened).

Among Ibn Sina's medical works, *Canon of Medicine,* is the ordered summation of all the medical knowledge up to his time. Divided into five books, this major work of Islamic medical tradition was used as the basic textbook for teaching medicine for seven centuries both in the East as well as in the West. Translated by Gerard of Cremona between 1150 and 1187, the *Canon* formed the basis of teaching at all European universities. It appears in the oldest known syllabus given to the School of Medicine at Montpellier, a bull of Pope Clement V dating from 1309, and in all subsequent ones until 1557. The Arabic text was edited at Rome in 1593; in all, eighty-seven translations, some incomplete, exist in various European languages.

Influence

Ibn Sina's influence on the subsequent development of intellectual thought is vast. In the Muslim world, his philosophy was instrumental in the emergence of *Ishraqi* (Illuminist) school of Suhrawardi. Ibn 'Arabi combined it with the Gnostic doctrines and Mulla Sadra integrated it into the intellectual perspectives of Shi'ism. In the West, medieval philosopher Thomas Aquinas embodied some of Ibn Sina's proofs in the Catholic theology and although the Renaissance brought a violent reaction against him, Ibn Sina holds a secure place in the history of Western philosophy through his influence on major Christian philosophers.

See also ARISTOTLE; AVERROËS; ISLAM; ISLAM, CONTEMPORARY ISSUES IN SCIENCE AND RELIGION; ISLAM, HISTORY OF SCIENCE AND RELIGION; THOMAS AQUINAS

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MUZAFFAR IQBAL

AXIOLOGY

An axiology is a theory about the nature of values and value judgments. Distinctions are usually made among *aesthetic values* (concerning the beauty of an object or action), *moral values* (concerning whether something is good or right), and *scientific* or *intellectual values* (concerning the coherence and adequacy of a theory). Nondualistic theories (Buddhism, Confucianism, process philosophy) deny these distinctions. Those who think value judgments are objective argue that the value of anything is measured by how well it imitates normative universals or conforms to the will of God. Empiricists, including most modern scientists, reject such objective universals. They treat values as subjective responses or judgments, as creations of personal preference or cultural tradition.

See also AESTHETICS; BEAUTY; VALUE

GEORGE ALLAN

B

BAHÁ’Í

The Bahá’í faith, a new and growing world religion, holds the unity and harmony of science and religion as one of its core principles. Science and religion, according to the Bahá’í teachings, are both equally necessary for humanity to progress. Science is the discoverer of the material and the spiritual reality of things, and it is the foundation of material and spiritual development. Religion develops both the individual and society, fostering the love, fellowship, and will that is necessary for humanity to advance. Science and religion counterbalance each other: Religion without science leads to superstition, whereas science without religion leads to materialism.

Historical origins

The Bahá’í faith originated in nineteenth-century Iran at a time when the country was struggling with economic and political instability, conflict between the religious and secular segments of society, and Russian and British expansionist policies. Iran was in decline under the Qajar dynasty when the Bábí millenarian movement was founded in 1844 by the Báb (Siyyid ‘Alí Muhammad, 1819–1850). The rapid rise of the Bábí movement and its prophecy of the coming of a world redeemer led to violent suppression, with its leaders either killed or sent into exile, as was the case for Bahá’u’lláh (Mírzá Husayn ’Alí, 1817–1892).

Bahá’u’lláh nursed the decimated Iranian Bábí community back to health from nearby Baghdad but was further exiled to Constantinople (modern Istanbul), to Adrianople (modern Edirne), and finally to Acre (modern Akko in Palestine). When he announced that he was the redeemer prophesied by the Báb, most of the Bábí community became Bahá’ís, followers of Bahá’u’lláh.

Bahá’u’lláh’s teachings were laid out in numerous books, epistles, and letters to a growing community. The central theme was unity: the unity of religion; the oneness of God; the unity of humanity; the equality of women and men; the need for a united world civilization, and the unity of science and religion. Religion promoted amity and concord as its chief aim, and this required the unfettered search after truth and the elimination of prejudice and superstition characteristic of science.

By the early twentieth century, the Bahá’í faith had spread around the world. ‘Abdu’l-Bahá (1844–1921)—Bahá’u’lláh’s eldest son and successor—traveled and spoke widely throughout Europe and North America, emphasizing that religion must be progressive. The great progress in technical and material spheres wrought by science necessitated similar progress in religion. “When religion, shorn of its superstitions, traditions, and unintelligent dogmas, shows its conformity with science,” he told his audiences, “then will there be a great unifying, cleansing force in the world which will sweep before it all wars, disagreements, discords and struggles” (1969, p. 146). Shoghi Effendi (1897–1957) succeeded ‘Abdu’l-Bahá. After his death, leadership passed to the Universal House of Justice seated in Haifa, Israel.

Bahá'í teachings about science and religion

The teachings of the Bahá'í faith are "founded upon the unity of science and religion and upon investigation of truth." Science and religion are like the two wings of one bird: "A bird needs two wings for flight, one alone would be useless. Any religion that contradicts science or that is opposed to it, is only ignorance—for ignorance is the opposite of knowledge. Religion which consists only of rites and ceremonies of prejudice is not the truth" ('Abdu'l-Bahá, 1969 p. 129).

The Bahá'í writings describe science as "the discoverer of realities," the means by which humanity explores and understands both material and spiritual phenomena:

> The virtues of humanity are many, but science is the most noble of them all. . . . It is a bestowal of God; it is not material; it is divine. Science is an effulgence of the Sun of Reality, the power of investigating and discovering the verities of the universe, the means by which man finds a pathway to God. Through intellectual and intelligent inquiry science is the discoverer of all things. ('Abdu'l-Bahá, 1982 p. 49)

The purpose of religion is to "safeguard the interests and promote the unity of the human race, and to foster the spirit of love and fellowship amongst men" (Bahá'u'lláh, 1978, p. 168). Human nature is fundamentally spiritual, and the "spiritual impulses set in motion by such transcendent figures as Krishna, Moses, Buddha, Zoroaster, Jesus, and Muhammad have been the chief influence in the civilizing of human character" (Bahá'í International Community). Religion and spiritual commitment are necessary if the fruits of science are to be used for the advancement of humanity: "In every sphere of human activity and at every level, the insights and skills that represent scientific accomplishment must look to the force of spiritual commitment and moral principle to ensure their appropriate application" (Bahá'í International Community).

Religious truth must be understood in the light of science and reason if it is not to become superstition and a source of discord. Religious doctrines that disagree with science are likely to disagree with doctrines of other religions, creating and sustaining religious conflict. However, this does not mean the current scientific point of view is necessarily fully correct, nor does it mean that truth is limited to only what science can explain.

Similarly, science alone is inadequate. Doctrines inspired by science—most notably, the view that only material things are real—have had pernicious and corrosive effects when imposed on the people of the world. These doctrines need to be counteracted by the truths of religion. 'Abdu'l-Bahá in *Paris Talks* emphasized that "with the wing of science alone he would also make no progress, but fall into the despairing slough of materialism" ('Abdu'l-Bahá 1969, p. 143). Furthermore, the commitment and the will that derives from religion is required if the results of science are to be applied to the benefit of the people of the world.

Evolution and the emergence of humanity. The Bahá'í writings address in depth the issue of evolution and the emergence of humanity—a major source of conflict between science and contemporary religion. Humanity is described as emerging by a gradual progression that starts at a simple material stage and advances degree by degree to the human stage. In each stage, according to 'Abdu'l-Bahá, humanity develops capacity for advancement to the next stage: "While in the kingdom of the mineral he was attaining the capacity for promotion into the degree of the vegetable. In the kingdom of the vegetable he underwent preparation for the world of the animal, and from thence he has come onward to the human degree, or kingdom" ('Abdu'l-Bahá 1982, p. 225). Evolutionary processes—indeed, all natural processes—are the expression of God's will and the mechanism for the unfolding of God's creation:

> Nature in its essence is the embodiment of My Name, the Maker, the Creator. Its manifestations are diversified by varying causes, and in this diversity there are signs for men of discernment. Nature is God's Will and is its expression in and through the contingent world (Bahá'u'lláh, p. 142).

Humanity, therefore, was created by God and potentially existed even before being actualized as a "composition of the atoms of the elements."

Humans and animals and are distinct and different kinds of beings, according to the Bahá'í view. It is incorrect to say that humans are descended from animals, even though physically that is the case. This is because humans have a rational and spiritual side in addition to the physical reality they share with animals: "The reality of man is his thought, not his material body. The thought force and the animal force are partners. Although man is part of the animal creation, he possesses a power of thought superior to all other created beings" ('Abdu'l-Bahá 1969, p. 17). The Bahá'í point of view therefore diverges from understandings of evolution that see no distinction between humans and animals. It reconciles two perspectives—natural evolution and divine creation—that many have deemed irremediably in conflict.

Types of knowledge. 'Abdu'l-Bahá describes human knowledge as being of two kinds. One kind "is the knowledge of things perceptible to the senses." The other kind "is intellectual—that is to say, it is a reality of the intellect; it has no outward form and no place and is not perceptible to the senses" ('Abdu'l-Bahá 1981, p. 83). The knowledge that people have of the laws of the universe is such an intellectual reality, as is the knowledge of God. 'Abdu'l-Bahá further describes four criteria for knowledge: sense perception (empiricism), reason (rationality), tradition, and inspiration. By itself, each criterion is inadequate: The senses can be fooled, reasonable thinkers differ, understanding of tradition is reasoned and gives differing interpretations, and the heart's promptings are not reliable. Only when evidence from all criteria is in agreement can a proof be trusted as reliable.

The Bahá'í model of how reliable knowledge is obtained gives a perspective for viewing the roles of science and religion in society. Purely empirical approaches or rational approaches to knowledge, even when combined as they are in science, are inadequate to meet social needs. Approaches based solely on tradition—prophetic or otherwise—or intuition and feeling are likewise inadequate. Rather, contributions from all the approaches are needed. Neither science nor religion separately provides the broad foundations by which society can progress. Both are needed.

Conclusion

The task facing humanity, according to the Universal House of Justice, the global Bahá'í administrative body, "is to create a global civilization which embodies both the spiritual and material dimensions of existence." Carrying out this task requires "a progressive interaction between the truths and principles of religion and the discoveries and insights of scientific inquiry." Science provides the understanding and technical capabilities that allow humanity to overcome the limitations of nature, making the goal of a peaceful and just world civilization an achievable one. Religion provides the moral, ethical, and spiritual strength, the discipline, and the commitment that are necessary if the goal is to become a reality.

See also EMERGENCE

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BEAUTY

Beauty, according to the ancient Greek philosopher Plato (c. 427–347 B.C.E.), is the most accessible of the Forms. Forms are transcendent sources of the essential qualities of things, the qualities that make things what they are. The proper relation among these qualities, their harmony, is what makes a thing beautiful. We are naturally drawn to beautiful things, wanting to possess them and to perpetuate their beauty in creations of our own. Our love of beauty leads us to seek it in increasingly more enduring forms of enjoyment and creation: from particular physical objects to friends and children, to public institutions and societal laws, to scientific theories and philosophical systems, and finally to Beauty itself. Thus Beauty is the harmonizing structure that give things their integrity, we desire it above all else, and in its presence we are able to create things of enduring worth. It is both the measure of our good and the enkindling agent for its accomplishment. Western notions of beauty since Plato are but a series of footnotes to these linked notions.

Objective interpretations

Aristotle emphasizes the notion of structure: The beauty of a thing lies in its formal and final causes, in the imposition of appropriate ordering principles of symmetry and unity upon indeterminate matter. He argues that for a work of art, such as a tragedy, to be excellent it must adhere to proper unities of time, place, and narrative sequence. Plotinus (205–270 C.E.) emphasizes the notion of beauty's lure, the ascent by its means to the timeless. Beauty is not merely symmetry and unity; it is a power irradiating them, for which we yearn and through which we can transcend that about us which is perishing. The early Christian theologian Augustine of Hippo (354–430 C.E.) identifies this power as God, through the beauty of whose Word our restless selves find salvation's rest.

Hence in Christianity, as in most religions, the actions and objects associated with worship are as beautifully crafted as possible, their beauty having the power to draw believers into the presence of the holy. Islam excludes the use of images, however, as did early radical Protestantism, finding them distractions rather than inducements. Contrast, for example, the severe elegance of Islam's Dome of the Rock mosque, or a clear-windowed New England Puritan church with the sculptured figures on the facade of the Roman Catholic cathedral at Chartres, or the ballet of icons and censors at a Russian Orthodox Eucharist.

Thomas Aquinas uses the beauty people see in the world around them, their sense of how things fit together, as a proof for the existence of God. Because they act together so as to attain the best result, they must be directed by a purposive being, as the arrow is directed by the archer. The ultimate source of such purposiveness is God. In the eighteenth century, William Paley (1743–1805) revived Aquinas's "argument from design," adapting it to the natural order described by Newtonian science. The well-ordered mechanistic intricacy of the world results from laws that cannot be fortuitous: the precision of a watch entails a watchmaker; the precision of the universe entails a God. People were no longer brought into God's presence through beauty, but from the beauty of nature at least it could be inferred that there must be a God who had created it.

The tendency since the rise of modern science, however, is to claim that nonsensible principles such as Beauty, although still timeless and necessary, are no longer understood as supernatural: they are the laws of nature. The Enlightenment *philosophe* Denis Diderot (1713–1784), for instance, defines beauty as the relations things possess by virtue of which we are able to understand nature in its genuine objectivity. Classicism in the arts is the claim that the timeless laws manifest in nature imply that there are rules derivable from those laws that apply to each artistic genre and that only if those rules are respected will the artist's work be beautiful. Similarly, scientists often argue that a machine works beautifully if it has been well designed, if its parts operate so that it fulfills its function smoothly and efficiently. The laws governing what works beautifully are themselves beautiful, and therefore laws that lack beauty are not likely to be adequate descriptions of what works. In this sense, a criterion of simplicity is often included in the conditions by which to assess a scientific hypothesis. For many purposes, Ptolemy's (90–168 C.E.) astronomy may be descriptively and predictively accurate, but its array of circles and epicycles are unnecessarily complicated and mathematically awkward compared to Johannes Kepler's (1571–1630) elegant ellipses. As William of Ockham (c. 1280–c. 1349) insisted, one should not multiply theoretical entities beyond necessity. Truth and Beauty, it would seem, have much in common after all.

Many thinkers, however, including most non-Western theorists, reject the notion that beauty is a universal objective reality. They argue that it is different in each of its instances. Beauty is the unique character of a thing, the way in which its specific elements are specifically related. The creation or the study of beautiful things is not a science but an art: conducting a tea ceremony, achieving inner peace through meditation or in action, freeing a statue from the marble block, telling an edifying story. For G. E. Moore (1873–1958), beauty is undefinable precisely because it is particular; it can only be directly experienced, like seeing the color red. Contemporary philosopher Mary Mothersill argues that a judgment of beauty is a logically singular judgment, based on radically contextual properties.

Subjective interpretations

Although there have always been those who claim that beauty is only in the eye of the beholder, modern science and the Cartesian separation of mind and body combined to reserve objectivity for physical bodies and their publicly-verifiable quantitative features. Beauty was therefore relegated to the realm of private mental things, to ideas and the sentiments. The Scottish philosopher David Hume (1711–1776) says that beauty is a matter of taste, a disinterested pleasure we take in certain of our sensations. The twentieth-century American poet and philosopher George Santayana (1863–1952) says beauty is pleasure objectified: pleasure experienced as the quality of a thing, our subjective responses projected onto their source.

The extreme version of subjectivism is found in the claim by C. K. Ogden and I. A. Richards, made in the 1950s, that aesthetic judgments have no truth functional significance: They are neither true nor false but rather emotive ejaculations akin to saying "wow." Marxist and Postmodernist forms of relativism make this subjectivism a function of race, ethnicity, religion (ideology), economic class, political power, or gender, critiquing objectivity claims as attempts to hide their self-serving character.

People often agree about what is beautiful, however, so even if beauty is a subjective feeling it can be argued that it has an objective cause. In the eighteenth century, the philosopher Francis Hutcheson (1694–1746), for instance, argued that on the basis of our sense perceptions we discern by a sixth sense a uniformity pervading their variety and call our pleasure in this beauty. Immanuel Kant (1724–1804) calls this sixth sense our common sense. As with all our other experiences, the experience of beauty involves both intuition and understanding, both sensations and concepts. But whereas for scientific and practical purposes the concepts are imposed on the sensations, ordering them meaningfully, when we experience something as beautiful we allow the free play of imagination to associate our perceptions with notions of meaning yet without their being imposed. We take what we experience as fraught with meaning but not any specifiable meaning. We take delight in this experience and so appreciate the world as involving more than what we can know about it or achieve by our actions upon it. Because these judgments involve conceptual and intuitive faculties that are the same for all human beings, they can be valid for others as well as ourselves: We have a common sense of beauty and hence our disputes about it can be rationally resolved.

Back to Plato

So Kant opens a way other than through politics, or religion, or scientific or philosophical theorizing for getting at the deeper realities underlying the world as it appears to us—through aesthetic appreciation and through the creation of works of art. Thus in the nineteenth century, Alexander Baumgarten (1714–1762) claimed that beauty is the sensory recognition of a transcendent unifying perfection. In the twentieth century, Martin Heidegger (1889–1976) argued that the beauty of a work of art, by disclosing the workly character of things, unconceals the creative source of the world's beings, their Being. We are back once more with Plato: There is a nonsensuous Reality disclosed by sensuous beauty, toward which we are drawn because of Beauty's power to break us free from the constraints of scientific understanding and our practical endeavors, to open us to the Good they obscure.

See also AESTHETICS; KANT, IMMANUEL; ORDER; PLATO; VALUE

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GEORGE ALLAN

BEHAVIORAL GENETICS

Behaviors distinguish human beings from other creatures and from each other. Genetic perspectives could help account for both the universals of human behavior (those shared by all) and the particulars (the individual differences). Behaviors are among the most complex attributes to study, but developments in behavioral genetics and the human genome project are producing new insights in this important area of study.

Behavioral genetics is a field that uses genetic methods to answer three questions about the nature and origin of individual differences in behavior: Is there good evidence for genetic influence on behavioral differences? How strong is this effect? Through what mediating steps do the genes influence the behavior? The manner in which such issues are addressed may have significant implications for one's conceptions of human nature, ethical responsibility, and freedom.

To answer these questions, behavioral geneticists use a variety of methods to study cognitive abilities, personality traits, psychiatric disorders, and other conditions. For example, results from family, twin, and adoption studies are carefully compared in order to analyze the differential effects of genetic background and rearing circumstances on the risk of specific behaviors in the offspring. Since the mid-1990s, the insights and methods developed in the human genome project have begun to shed light on the molecular pathways involved in brain development and function. This knowledge in turn may lead to better methods of intervention or treatment that are adapted to an individual's genetic makeup.

Such a strategy differs from that used in two other approaches. Behaviorism arose as a protest against introspective psychology and emphasized observable behavior in response to environmental stimuli, thus implying that behavior is shaped entirely by environmental forces. Sociobiology, on the other hand, emphasizes the role of an evolved, species-typical, nature for the behavior of a given organism.

Behavioral geneticists accept the view that behavior is influenced by both nature and nurture, but recent studies have shown that these components are not as independent as they were once thought to be. Some genes influence the way individuals select and shape experiences, while other genes can affect an individual's susceptibility to these experiences. Careful research designs are needed to sort out such gene/environment interactions and correlations.

Contrary to reports of a "novelty-seeking gene" or a "schizophrenia gene," researchers do not expect to find a single gene that explains a specific behavior (except in rare cases). Instead, multiple genes are associated with aspects of brain functioning that mediate one's preferences and capacities; these in turn influence one's likelihood of showing that behavior. In such situations any specific gene is likely have only a small effect.

Genetic research methodology may be inherently reductionistic, but this need not lead to explanatory reductionism. Genes never act in isolation, and their effects must always be interpreted in context. Individual genes can be turned on or off in response to signals from their environment, with the result that gene expression can even be modified indirectly by social interaction.

Clearly any evidence that DNA defines human beings and shapes their decision-making would appear to be incompatible with traditional understandings of human freedom and moral responsibility. The findings from behavioral genetics, however, indicate that genetic influences should be understood more as predispositions or limiting factors. An individual's genome may set boundaries on various traits and potential, but it does not determine how one will organize his or her life within those parameters.

In summary, genes are necessary for human existence and give people the ability to express those qualities that are distinctively human. Genes are not sufficient to account for all differences in behavior, however, since interactions with environment and individual experience are involved throughout life. An adequate view of human nature should be informed by an understanding of the effects of genes at many levels. Future research is likely to provide further evidence of the contributions of genes to psychological, social, moral, and religious behaviors.

See also BEHAVIORISM; SOCIOBIOLOGY

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BEHAVIORISM

Behaviorism as a positivistic anti-metaphysical science presupposes a highly mechanistic one-dimensional view of the human person and therefore is often seen as an attack on transcendence, the human soul, and human freedom. The British-American psychologist William McDougall (1871-1938) introduced behaviorism in *Psychology: The Study of Behavior* (1912) and independently the American psychologist John B. Watson (1878–1958) in his article "Psychology as a Behaviorist Views It" (1913). Watson began his essay stating: "Psychology as the behaviorist views it is a purely objective experimental branch of natural science. Its theoretical goal is the prediction and control of behavior" (p. 158). McDougall later distanced himself from Watson's mechanistic approach.

The predecessors of behaviorism

Among the predecessors of behaviorism were the British empiricist philosophers, including David Hume (1711–1776), who contended that sense impressions produce all ideas. American philosopher John Dewey (1859–1952), with whom Watson studied at the University of Chicago, introduced functionalism, which was concerned with the use of consciousness and behavior. Biologist Jacques Loeb (1859–1924), one of Watson's professors at Chicago, explained animal behavior in purely physical-chemical terms. Russian reflexology merged the mind with the brain, which was then explained in terms of reflexes; physiologist Ivan Pavlov (1849–1936) introduced experiential analysis of reflexes and their conditioning, and neurologist Vladimir Bekhterev (1857–1927) influenced Watson's interpretation of emotional behavior.

By drawing on neighboring branches of the sciences, behaviorists attempted to turn psychology into a hard science. In 1879, philosopher and psychologist Wilhelm Wundt (1832–1920) established an institute of experimental psychology in Leipzig, Germany. But Watson chided Wundt and his students that despite having made psychology into a science without soul, despite replacing the term *soul* with *consciousness,* they still maintained a dualistic concept of the human being. Since both soul and human consciousness elude the purely objective experimental method, they cannot be quantified and therefore do not exist for Watson. His methodological behaviorism, disallowing for the duality of mind and matter, was a materialistic monism or even a scarcely disguised atheism.

Methodological behaviorism

Between 1912 and the mid-1900s, methodological behaviorism dominated psychology in the United States and also had a wide international impact. Most important for the wider populous was the theory of learning, which was explained wholly or largely on facts and methods of conditioning.

From approximately 1930 to 1950 psychological research moved from the classic behaviorism of Watson to a neo-behaviorism. Psychologist Jacob Robert Kantor (1888–1984), schooled at the University of Chicago, believed that behavior was dependent upon the interaction of an organism with its environment. His "Organismic Psychology," later renamed "Interbehavioral Psychology," was promoted as an antidote to the notion that parts of the organism ad a causal responsibility for the rest of the organism's action.

Radical behaviorism

In his 1938 book *The Behavior of Organisms: An Experimental Analysis,* psychologist B. F. Skinner (1904–1990) introduced radical behaviorism. Skinner insisted that behavior should be studied as a function of external variables apart from any reference to mental or physiological states or processes. For him psychology was an experimental natural science. Fundamental to his approach was the analysis of behavior in light of stimuli. In 1948, he wrote *Walden Two,* a utopian novel where a social environment free of governments, religions, and capitalistic enterprises produced a "good life." In this work, Skinner advocated what some called behavioral engineering. In his book *Beyond Freedom and Dignity* (1971) Skinner asserted that the abolition of the concept of autonomous humanity is overdue. Rather, Skinner believed that human beings are controlled by their environment. The question is whether this control should be left to accidents, to tyrants, or to people themselves. Therefore Skinner opted for designing an existence aided by psychology which enables a happy life, defined by his wholehearted endorsement of the capitalistic system and his critical view of government and religion.

In 1932, psychologist Edward C. Tolman (1886–1959) published *Purposive Behavior in Animals and Man* in which he incorporated motifs and perceptions into psychological consideration. Purpose to him had not a theological, but a teleological meaning. Although Tolman was as skeptical about religion as the behaviorists who preceded him, he introduced a more holistic approach to behaviorism. Nevertheless he developed mechanistic rules to account for observed behavior.

Psychologist Clark L. Hull (1884–1952) distinguished between scientific empiricism and scientific theory in his 1943 book *Principles of Behavior: An Introduction to Behavior Theory.* While Hull did not deny the existence of a mind or a consciousness, he did not insist on its basic, logical, priority. Yet the mind was not a means for solving problems; to the contrary, it itself was a problem. This means that Hull was open to the insights of neurophysiology.

Behaviorism since the 1950s

At least since the 1950s, increasing skepticism arose about the claims of behaviorism, and a new humility emerged. Behaviorism never abandoned its scientific rigor, but rather became more multifaceted. While some continued to pursue the discernment of behavior using the language and the terms of physical science, others pursued a more teleological track by alternatively trying to understand why behavior is created and how behavior is created.

Even a new realism emerged with regard to human nature and its potential. Behavioral scientists such as zoologist Konrad Lorenz (1903–1989) no longer explained away evil, but understood aggressive behavior as an inherent part of life. In its excessive varieties, however, aggression signaled a breakdown of cultural ethos. Ethologists such as Irenaeus Eibl-Eibesfeldt (b. 1928) have shown that humans follow some inborn norms according to which they interact with the environment, such as fear of strangers and smiling during pleasant experiences. Finally, sociobiologists such as Edward O. Wilson (b. 1929) suggest that a species neither responds just to stimuli, as classical behaviorism maintained, nor is it only instinctively fixed. Rather, a species uses whatever is advantageous to its evolution.

Behaviorism has helped the experimental method become a constituent part of psychological research. Psychology has moved from philosophy and physiology to an independent enterprise in its own right by utilizing the tools and methods of physics, chemistry, computer science, and statistics. However, it is evident that although certain principles are demonstrated in the laboratory, there is no guarantee that they are significant outside it. The reductive nature of the laboratory is quite different from the complexity of the natural environment. We can never infer from laboratory experiments that we have identified all or even the most critical influences in nature.

In its history behaviorism has not rejected rigorous experimental and observational emphasis, but has become more discerning and tentative in its claims. It has realized that a human being is a complicated biological being whose socialization has greater influence in its development than is the case with other biological beings. Therefore a strictly mechanistic one-dimensional view has been found wanting. This multifaceted approach to human behavior opens the possibility for a renewed dialogue with the humanities, including theology, on such issues as human freedom and responsibility and even on transcendence.

See also AGGRESSION; HUME, DAVID; PSYCHOLOGY; PSYCHOLOGY OF RELIGION

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BIBLICAL COSMOLOGY

Cosmogony is the study of the creation of the universe. The Bible begins with God creating the heaven and the Earth, then the sun, moon, and stars, followed by every living creature that moves, and finally human beings, in God's own image (Gen. 1:1, 16, 21, 26). *Cosmology* examines the structure and evolution of the universe. The biblical worldview makes no provision for evolution; its universe is static, except for God's miracles. Regarding structure, God is said to have stretched out the firmament (heaven) like a tent (Ps. 103:2), rather than a sphere or the infinite expanse of later scientific beliefs. God's intervention on behalf of the army of Joshua, when God commanded the sun to stand still (Josh. 10:12–14), implies that the sun revolves around the Earth, rather than Earth rotating. Inevitably, aspects of biblical cosmology written long ago now conflict with changing scientific belief.

See also COSMOLOGY, RELIGIOUS AND PHILOSOPHICAL ASPECTS; GENESIS

NORRISS HETHERINGTON

BIBLICAL INTERPRETATION

See SCRIPTURAL INTERPRETATION

BIG BANG THEORY

The Big Bang Theory is based on the observation that all the stars and galaxies of the universe are in motion and not stationary. The American astronomer Edwin Hubble (1889–1953) discovered in 1929 that the light of all visible stars was redshifted. Hence the movement of the myriad of galaxies is not random but everything is moving further away. If all galaxies are now racing away from one another then at one point all matter must have been clustered together in an infinitely dense space and its present motion might best be explained by an original explosion of matter. Hence the term *Big Bang*. The 1965 discovery by Arno Penzias (b. 1933) and Robert Wilson (b. 1936) of the background radiation produced by the intense heat of this "explosion" served to further confirm the theory. The Big Bang Theory brought to an end the idea of a static universe and made respectable again discussions of the beginning and possible creation of the universe.

See also BIG CRUNCH THEORY; COSMOLOGY, PHYSICAL ASPECTS; CREATION; INFLATIONARY UNIVERSE THEORY

MARK WORTHING

BIG CRUNCH THEORY

The Big Crunch Theory is made possible by Big Bang cosmology, which states that all matter in the universe is now racing away from all other matter. If there is enough matter in the universe to create a gravitational force sufficient to bring this movement to a halt and to reverse its direction, then at some point in the remote future all matter in the universe will converge into an infinitely dense point in space, resembling a massive black hole. The end of the universe would then resemble its beginning—a singularity at which the laws of physics as we know them no longer apply. Such a universe is called a *closed universe.*

See also BIG BANG THEORY; CLOSED UNIVERSE; COSMOLOGY, PHYSICAL ASPECTS; SINGULARITY

MARK WORTHING

BIOCULTURAL EVOLUTION

See EVOLUTION, BIOCULTURAL

BIOLOGICAL DIVERSITY

Biological diversity, or biodiversity, is a generic term for the variety of life on Earth. Such variety is described in Genesis as the "swarms" of creatures Earth brings forth (Gen. 1:20-25). One basic measure of biodiversity is species, though other indicators run a spectrum from genetic alleles (variants) through ecosystems and landscapes. Estimates of the total number of existing species vary from three to ten million (and as much as thirty million), with about 1.5 million described. The unknowns are mostly small invertebrates and microorganisms. Contemporary species inherit their diversity from forms that have gone extinct; diversity overall has increased over evolutionary history. Estimates of the number of species that humans place in jeopardy run from fifteen percent to twenty-five percent of the total. Scientists and religious persons may differ about evolutionary origins but seldom differ about the urgency of conserving biodiversity.

See also ECOLOGY; EVOLUTION

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BIOLOGY

Biology is defined as the science of living organisms. The diversity of activities contained within the field of biology is immense, and includes research into the origins, functions, and interrelationships of organisms, as well as the technological application of biological knowledge.

The idea that living forms gradually emerged through a process of evolution from much simpler forms in a branch-like system is no longer a contested issue in biology. Research into the fossil record, or palaeontology, and other subdisciplines of biology, such as comparative anatomy, biogeography, embryology, and genetics, have helped to trace patterns of common descent, including those between humans and primates. Charles Darwin's (1809–1882) theory of natural selection forms the basis of evolutionary theory, though other processes such as genetic drift and molecular drive have been proposed in addition. The relative pace of natural selection continues to be the subject of ongoing debate. The dynamics of genetic change in a population include mutation rates, migration of individuals from one population to another, genetic drift, and natural selection. The anatomical and behavioral differences within and among known hominid species can be traced. Other extinct species of humans have been discovered, though the consensus seems to be that *Homo sapiens* has a single original ancestor, who probably lived in Africa.

Ecology has enabled scientists to study more closely the way living organisms relate to each other. While early ecologists believed that ecosystems were stable and in equilibrium, this thesis has gradually given way to a more dynamic view, where contingency is predominant. Ecology includes not just the relationship between local communities of living things, but also extends to wider global and planetary systems. Some ecologists emphasize the idea of self-regulation within living systems, or autopoiesis, as well as the idea of emergence, understood in terms of properties that cannot simply be explained by upward causation from molecular mechanisms. Biosemiotics applies concepts from semiotics to elaborate the specific emergence of meaning, intentionality, and a psychic world. The latter can be compared to sociobiology, which tries to explain particular aspects of animal and human behavior by envisaging a shared biological and genetic origin.

The use of biological research to address specific human needs through biotechnology was given a radical boost following the discovery of the structure of deoxyribonucleic acid (DNA) in the 1950s. The ability to move genes from one species to the next has opened up the possibility of even more radical human intervention in the evolutionary process. The most controversial changes are those that manipulate the human species. Nonetheless, changes in the nonhuman world also raise questions that are of concern to environmentalists. The general increase in technological and industrial activity has put considerable strain on the planet, which many biologists consider to be near its carrying capacity in terms of its ability to support the human population. Loss of species through, for example, habitat destruction, climate change, or direct exploitation has promoted a growing concern for an environmental ethic among secular and religious communities. Such questions move biology outside the realm of pure science into the realms of the politics and the economics of poverty, posterity, and social justice.

See also BIOSEMIOTICS; EVOLUTION; LIFE, ORIGINS OF; LIFE, RELIGIOUS AND SPIRITUAL ASPECTS; LIFE SCIENCES; SOCIOBIOLOGY

CELIA DEANE-DRUMMOND

BIOSEMIOTICS

Biosemiotics is a growing field that studies the production, action, and interpretation of signs (such as sounds, objects, smells, movements, but also signs on molecular scales normally not perceived by an organism) in the physical and biologic realm in an attempt to integrate the findings of biology and semiotics (the study of signs and symbols). One goal of biosemiotics is to form a new view of life and meaning as immanent features of the natural world.

Early pioneers of biosemiotics include Charles S. Peirce (1839–1914), Charles Morris (1901-1979), Jakob von Uexküll (1864-1944), Heini Hediger (1908-1992), Giorgio Prodi (1928-1987), Thomas A. Sebeok (1920-2001), and Thure von Uexküll (b.1908). Contemporary scholars include the biologists Jesper Hoffmeyer (b.1942), Kalevi Kull (b.1952), Alexei Sharov (b. 1954), and semioticians Floyd Merrell (b.1937), John Deely (b. 1942), Winfried Nöth (b. 1944), and Lucia Santaella (b.1944).

One of the central characteristics of living systems is the highly organized nature of their physical and chemical processes. These processes are based, in part, on the informational and molecular properties of what came to be known in the 1960s as the *genetic code*. Some distinguished biologists, such as Ernst Mayr, have viewed these properties as processes that distinguish life from anything else in the physical world, except, perhaps, computers. However, although the informational teleology (i.e., god-directedness based on the stored informational code) of a computer program is not an original form of teleology because the program is designed by humans to achieve specific goals, the teleology and informational characteristics of organisms are intrinsic because they evolved naturally through evolutionary processes. Traditional biology has regarded such processes as purely physical, adopting a restricted notion of the physical as having to do with only "efficient causation."

Biosemiotics attempts to use semiotic concepts to answer questions about the biologic and evolutionary emergence of meaning, intentionality, and a psychic world. Such questions are difficult to answer within a purely mechanist and physicalist framework. Biosemiotics sees the evolution of life and the evolution of semiotic systems as two aspects of the same process. The scientific approach to the origin and evolution of life has given us highly valuable accounts of the external aspects of the process, but has overlooked the inner qualitative aspects of sign action, leading to a reduced picture of causality.

Complex self-organized living systems are governed by formal and final causality. Such systems are *formal* in the sense of their *downward causation* from a whole structure (such as the organism) to its individual molecules, constraining their action but also endowing them with functional meanings in relation to the whole metabolism. Systems are *final* in the sense of their tendency to take habits and to generate future interpretants of the present sign actions. In this sense, biosemiotics draws upon the insights of fields like systems theory, theoretical biology, and the physics of complex self-organized systems.

Particular scientific fields like molecular biology, cognitive ethology, cognitive science, robotics, and neurobiology deal with information processes at various levels and thus spontaneously contribute to knowledge about *biosemiosis* (sign action in living systems). However, biosemiotics is not yet a specific disciplinary research program, but a general perspective on life that attempts to integrate such findings, and to build a new foundation for biology. It may help to resolve some forms of Cartesian dualism that are still haunting philosophers and scientists. By describing the continuity between matter and mind, biosemiotics may also help people understand higher forms of mind and the variety of religious experiences, although real interaction between biosemiotics and theology has yet to come.

See also BIOLOGY; CAUSATION; EMERGENCE; SEMIOTICS

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CLAUS EMMECHE

BIOTECHNOLOGY

Biotechnology is a set of techniques by which human beings modify living things or use them as tools. In its modern form, biotechnology uses the techniques of molecular biology to understand and manipulate the basic building blocks of living things. The earliest biotechnology, however, was the selective breeding of plants and animals to improve their food value. This was followed in time by the use of yeast to make bread, wine, and beer. These early forms of biotechnology began about ten thousand years ago and lie at the basis of human cultural evolution from small bands of hunter-gatherers to large, settled communities, cities, and nations, giving rise, in turn, to writing and other technologies. It is doubtful that, at the outset, the first biotechnologists understood the effects of their actions, and so the reason for their persistence in pursuing, for example, selective breeding over the hundreds of generations necessary to show much advantage in food value, remains something of a mystery.

The world's historic religions emerged within the context of agriculture and primitive biotechnology, and as one might expect they are at home in that context, for instance through their affirmation of agricultural festivals. In addition, Christianity took the view that nature itself has a history, according to which, nature originally was a perfectly ordered garden, but as a result of human refusal to live within limits, nature was cursed or disordered by its creator. The curse makes nature at once historic, disordered, both friendly and hostile to human life, and open to improvement through human work. These effects fall especially on human agriculture and childbirth, both of which are focal areas of biotechnology.

By the time of Charles Darwin (1809–1882), plant and animal breeders were deliberate and highly successful in applying techniques of selective breeding to achieve specific, intended results. Darwin's theory of evolution is built in part on his observation of the ability of animal breeders to modify species. The work of human breeders helped Darwin see that species are variable, dynamic, and subject to change. Inspired by the success of intentional selective breeding, Darwin proposed his theory of natural selection, by which nature unintentionally acts something like a human breeder. Nature, however, uses environmental selection, which favors certain individuals over others in breeding. The theory of natural selection, of course, led to a profound shift in human consciousness about the fluidity of life, which in turn fueled modern biotechnology and its view that life may be improved. While Christianity struggled with other implications of Darwinism, it did not object to the prospect that human beings can modify nature, perhaps even human nature.

The emergence of modern biotechnology

In the twentieth century, as biologists refined Darwin's proposal and explored its relationship to genetics, plant breeders such as Luther Burbank (1849–1926) and Norman Borlaug (1914–) took selective breeding to new levels of success, significantly increasing the quality and quantity of basic food crops. But it was the late twentieth-century breakthroughs in molecular biology and genetic engineering that established the technological basis for modern biotechnology. The discovery that units of hereditary information, or genes, reside in cells in a long molecule called deoxyribonucleic acid (or DNA) led to an understanding of the structure of DNA and the technology to manipulate it. Biotechnology is no longer limited to the genes found in nature or to those that could be moved within a species by breeding. Bioengineers can move genes from one species to another, from bacteria to human beings, and they can modify them within organisms.

The discovery in 1953 of the structure of DNA by Francis Crick (b. 1916) and James Watson (b. 1928) is but one key step in the story of molecular biology. Within two decades, this discovery opened the pathway to the knowledge of the so-called genetic alphabet or code of chemical bases that carry genetic information, an understanding of the relationship between that code and the proteins that result from it, and the ability to modify these structures and processes (genetic engineering). The decade of the 1980s saw the first *transgenic* mammals, which are mammals engineered to carry a gene from other species and to transmit it to their offspring, as well as important advances in the ability to multiply copies of DNA (polymerase chain reaction or PCR). The Human Genome Project, an international effort begun around 1990 to detail the entire DNA information contained in human cells, sparked the development of *bioinfomatics,* the use of powerful computers to acquire, store, share, and sort genetic information. As a result, not only is a standard human DNA sequence fully known (published in February 2001), but it is now possible to determine the detailed code in any DNA strand quickly and cheaply, a development likely to have wide applications in medicine and beyond.

Biotechnology is also dependent upon embryology and reproductive technology, a set of techniques by which animal reproduction is assisted or modified. These techniques were developed largely for agricultural purposes and include artificial insemination, in vitro fertilization, and other ways of manipulating embryos or the gametes that produce them. In 1978, the first in vitro human being was born, and new techniques are being added to what reproductive clinics can do to help women achieve pregnancy. These developments have been opposed by many Orthodox Christian and Roman Catholic theologians, by the Vatican, and by some Protestants, notably Paul Ramsey. Other faith traditions have generally accepted these technologies. In addition, some feminist scholars have criticized reproductive medicine as meeting the desires of men at the expense of women and their health.

Reproductive medicine, however it may be assessed on its own merits, does raise new concerns when it is joined with other forms of biotechnology, such as genetic testing and genetic engineering. In the 1990s, in vitro fertilization was joined with genetic testing, allowing physicians to work with couples at risk for a genetic disease by offering them the option of conceiving multiple embryos, screening them for disease before implantation, and implanting only those that were not likely to develop the disease. This technique, known as *preimplantation diagnosis,* is accepted as helpful by many Muslim, Jewish, and Protestant theologians, but is rejected by Orthodox Christians and in official Catholic statements. The ground for this objection is that the human embryo must be shown the respect due human life, all the more so because it is weak and vulnerable. It is permissible to treat the embryo as a patient, but not to harm it or discard it in order to treat infertility or to benefit another. The usual counterargument is to reject the view that the embryo should be respected as a human life or a person.

The significance of stem cells and cloning

Developments in cloning and in the science and technology of stem cells offer additional tools for biotechnology. In popular understanding, cloning is usually seen as a technique of reproduction, and of course it does have that potential. The birth of Dolly, the cloned sheep, announced in 1997, was a surprising achievement that suggests that any mammal, including human beings, can be created from a cell taken from a previously existing individual. Many who accept reproductive technology generally, including such techniques as in vitro fertilization, found themselves opposing human reproductive cloning, but they are not sure how to distinguish between the two in religiously or morally compelling ways. With few exceptions, however, religious institutions and leaders from all faith traditions have opposed human reproductive cloning, if only because the issues of safety seem insurmountable for the foreseeable future. At the same time, almost no one has addressed the religious or moral implications of the use of reproductive cloning for mammals other than human beings, although it has been suggested that it would not be wise or appropriate to use the technique to produce large herds of livestock for food because of the risk of a pathogen destroying the entire herd.

The technique used to create Dolly—the transfer of the nuclear DNA from an adult cell to an egg, thereby creating an embryo and starting it through its own developmental process—can serve purposes other than reproduction, and it is these other uses that are especially interesting to biotechnology. Of particular interest is the joining of the nuclear transfer technique with the use of embryonic stem cells to treat human disease. In 1998, researchers announced success in deriving human embryonic stem cells from donated embryos. These cells show promise for treating many diseases. Once derived, they seem to be capable of being cultured indefinitely, dividing and doubling in number about every thirty hours. As of 2002, researchers have some confidence that these cells can be implanted in the human body at the site of disease or injury, where they can proliferate and develop further, and thereby take up the function of cells that were destroyed or impaired.

Stem cells, of course, can be derived from sources other than the embryo, and research is underway to discover the promise of stem cells derived from alternative sources. There are two advantages in using these other sources. First, no embryos are destroyed in deriving these cells. For anyone who sets a high standard of protection for the human embryo, the destruction of the embryo calls into question the morality of any use of embryonic stem cells. Second, the use of stem cells from sources other than an embryo may mean that in time, medical researchers will learn how to derive healing cells from the patient's own body. The advantage here is that these cells, when implanted, will not be rejected by the patient's immune system. Embryonic stem cells, which may have advantages in terms of their developmental plasticity, are decidedly problematic because of the immune response.

One way to eliminate the immune response is to use nuclear transfer to create an embryo for the patient, harvesting stem cells from that embryo (thereby destroying it) and implanting these cells in the patient. Because they bear the patient's DNA, they should not be rejected. This approach is medically complicated, however, and involves the morally problematic step of creating an embryo to be destroyed for the benefit of another.

Nonhuman applications

As a result of the developments in the underlying science and technologies, biotechnology is able to modify any form of life in ways that seem to be limited only by the imagination or the market. Biotechnology has produced genetically modified microorganisms for purposes ranging from toxic waste clean-up to the production of medicine. For example, by inserting a human gene into a bacterium that is grown in bulk, biotechnology is able to create a living factory of organisms that have been engineered to make a specific human protein. Such technologies may also be used to enhance the virulence of organisms, to create weapons for bioterrorism, or to look for means of defense against such weapons. Aside from obvious concerns about weapons development, religious institutions and scholars have not objected to these uses of biotechnology, although some Protestant groups question the need for patents, especially when sought for specific genes.

Plants, perhaps the first organisms modified by the earliest biotechnology, remain the subject of intense efforts. Around the year 2000, major advances were made in plant genome research, leading to the possibility that the full gene system of some plant species can be studied in detail, and the ways in which plants respond to their environment may be understood as never before. Some attention is given to plants for pharmaceutical purposes, but the primary interest of biotechnology in plants is to improve their value and efficiency as sources of food. For instance, attempts have been made to increase the protein value of plants like rice. The dependence of farm plants on fertilizer and pesticides may also be reduced using biotechnology to engineer plants that, for instance, are resistant to certain insects.

In the 1990s, the expanding use of genetically modified plants in agriculture was met with growing concerns about their effects on health and on the environment. Adding proteins to plants by altering their genes might cause health problems for at least some who consume the plants, perhaps through rare allergic reactions. Genes that produce proteins harmful to some insects may cause harm to other organisms, and they might even jump from the modified farm plant to wild plants growing nearby. Furthermore, some believe that consumers have a right to avoid food that is altered by modern biotechnology, and so strict segregation and labeling must be required. Deeply held values about food and, to some extent, its religious significance underlie many of these concerns. In Europe and the United Kingdom, where public opposition to genetically modified food has been strong, some churches have objected to excessive reliance upon biotechnology in food production and have supported the right of consumers to choose, while at the same time recognizing that biotechnology can increase the amount and the value of food available to the world's neediest people.

Animals are also modified by biotechnology, and this raises additional concerns for animal welfare. Usually the purpose of the modification is related to human health. Biotechnologists may, for example, create animals that produce pharmaceuticals that are expressed, for instance, in milk, or they may create animal research models that mimic human disease. These modifications usually involve a change in the animal germline—that is, they are transmissible to future generations and they affect every cell in the body. Such animals may be patented, at least in some countries. All this raises concern about what some see as the commodification of life, the creation of unnecessary suffering for the animals, and a reductionistic attitude toward nature that sees animals as nothing but raw materials that may be reshaped according to human interest.

Human applications

It is the human applications of biotechnology, however, that elicit the most thorough and intense religious responses. As of 2002, genetic technologies are used to screen for a wide range of genetic conditions, but treatments for these diseases are slow to develop. Screening and testing of pregnancies, newborns, and adults have become widespread in medicine, and the resulting knowledge is used to plan for and sometimes prevent the development of disease, or to terminate a pregnancy in order to prevent the birth of an infant with foreseeable health problems. Some religious bodies, especially Roman Catholic and Orthodox Christian, vigorously criticize this use of genetic testing. One particular use of prenatal testing—to identify the sex of the unborn and to abort females—is thought to be widespread in cultures that put a high priority on having sons, even though it is universally criticized. It is believed that the uses of testing will grow, while the technologies to treat disease will lag behind.

Attempts at treatment lie along two general pathways: pharmaceuticals and gene therapy. Biotechnology offers new insight into the fundamental processes of disease, either by the creation of animal models or by insight into the functions of human cells. With this understanding, researchers are able to design pharmaceutical products with precise knowledge of their molecular and cellular effects, with greater awareness of which patients will benefit, and with fewer side effects. This is leading to a revolution in pharmaceutical products and is proving to be effective in treating a range of diseases, including cancer, but at rapidly increasing costs and amidst growing concerns about access to these benefits, especially in the poorest nations.

Gene therapy, begun in human beings in 1990, tries to treat disease by modifying the genes that affect its development. Originally the idea was to treat the classic genetic diseases, such as Tay Sachs or cystic fibrosis, and it is expected that in time this technique will offer some help in treating these diseases. But gene therapy will probably find far wider use in treating other diseases not usually seen as genetic because researchers have learned how genes play a role in the body's response to every disease. Modifying this response may be a pathway to novel therapies, by which the body treats itself from the molecular level. For instance, it has been shown that modified genes can trigger the regeneration of blood vessels around the heart. In time these approaches will probably be joined with stem cell techniques and with other cell technologies, giving medicine a range of new methods for modifying the body in order to regenerate cells and tissues.

Religious opinion has generally supported gene therapy, seeing it as essentially an extension of traditional therapies. At the same time, both religious scholars and bioethicists have begun to debate the prospect that these technologies will be used not just to treat disease but to modify traits, such as athletic or mental ability, that have nothing to do with disease, perhaps to enhance these traits for competitive reasons. Many accept the idea of therapy but reject enhancement, believing that there is a significant difference between the two goals. Many scholars, however, are skeptical about whether an unambiguous distinction can be drawn, much less enforced, between therapy and enhancement. Starting down the pathway of gene therapy may mean that human genetic enhancement is likely to follow. This prospect raises religious concerns that people who can afford to do so will acquire genetic advantages that will lead to further privilege, or that people will use these technologies to accommodate rather than challenge social prejudices.

It is also expected that these techniques will be joined with reproductive technologies, opening the prospect that future generations of humans can be modified. The prospect of such germline modification is greeted with fear and opposition by many, usually for reasons that suggest religious themes. In Europe, germline modification is generally rejected as a violation of the human rights of future generations, specifically the right to be born with a genome unaffected by technology. In the United States, the opposition is less adamant but deeply apprehensive about issues of safety and about the long-term societal impact of what are popularly called "designer babies." Religious bodies have supported these concerns and have called either for total opposition or careful deliberation.

How far biotechnology can go is limited by the complexities of life processes, in particular in the subtleties of interaction between DNA and the environment. Biotechnology itself helps researchers discover these subtleties, and as much as biotechnology depends upon the sciences of biology and genetics, it must be noted that the influence between technology and science is reciprocal. The Human Genome Project, for instance, opened important new questions about human evolution and about how DNA results in proteins. Knowledge of the genomes of various species reveals that the relationship between human beings and distant species, such as single-celled or relatively simple organisms, turns out to be surprisingly close, suggesting that evolution conserves genes as species diverge.

Perhaps even more surprising is the way in which the Project has challenged the standard view in modern genetics of the tight relationship between each gene and its protein, the so-called dogma of one gene, one protein. It turns out that human beings have about one hundred thousand proteins but only about thirty-three thousand genes, and that genes are more elusive and dynamic than once thought. It appears that DNA sequences from various chromosomes assemble to become the functional gene, the complete template necessary to specify the protein, and that these various sequences can assemble in more than one way, leading to more than one protein. Such dynamic complexity allows some thirty-three thousand DNA coding sequences to function as the templates for one hundred thousand proteins. But this complexity, in view of the limited understanding of the processes that define it, means that the ability to modify DNA sequences may have limited success and unpredictable consequences, which should lower confidence in genetic engineering, especially when applied to human beings.

Biotechnology is further limited by financial factors. Most biotechnology is pursued within a commercial context, and the prospect of near-term financial return must be present to support research. Biotechnology depends upon access to capital and upon legal protection for intellectual property, such as the controversial policy of granting patent protection on DNA sequences or genes and on genetically modified organisms, including mammals. This financial dependence is itself a matter of controversy, giving rise to the fear that life itself is becoming a mere commodity or that the only values are those of the market.

A look ahead

There is no reason, however, to think that biotechnology has reached the limits of its powers. On the contrary, biotechnology is growing not just in the scope of its applications but in the range and power of its techniques. Biotechnology's access to the whole genomes of human beings and other species means that the dynamic action and interaction of the entire set of genes can be monitored. In one sense, the completion of full genomes ushers in what some have called post-genomic biotechnology, characterized by a new vantage point of a systematic overview of the cell and the organism. This is proving valuable, for instance, in opening new understandings of cancer as a series of mutation events within a set of cells in the body. Attention is turning, however, from the study of genes to the study of proteins, which are more numerous than genes but also more dynamic, coming quickly into and out of existence in the trillions of cells of the human body according to precise temporal and spatial signals. Most human proteins are created only in a small percentage of cells, during a limited period of human development, and only in precisely regulated quantities. Studying this full set of proteins, in all its functional dynamism, is a daunting task requiring technologies that do not exist at the beginning of the twenty-first century. The systematic study of proteins, called *proteomics,* may in fact become a new international project for biology, leading in time to a profound expansion of the powers of biotechnology.

In time, researchers will develop powerful new methods for modifying DNA, probably with far higher precision and effectiveness than current techniques allow, and perhaps with the ability to transfer large amounts of DNA into living cells and organisms. Computer power, which is essential to undertakings like the Human Genome Project and to their application, continues to grow, along with developments such as the so-called gene chip, using DNA as an integrated part of the computing device. Advances in engineering at the very small scale, known as *nanotechnology* (from *nanometer,* a billionth of a meter), suggest that molecular scale devices may someday be used to modify biological functions at the molecular level. For instance, nanotechnology devices in quantity may be inserted into the human body to enter cells, where they might modify DNA or other molecules. In another area of research, scientists are exploring the possibility that DNA itself may be used as a computer or a data storage device. DNA is capable of storing information more efficiently than current storage media, and it may be possible to exploit this capacity.

It is impossible to predict when new techniques will be developed or what powers they will bring. It is clear, however, that new techniques will be found and that they will converge in their effectiveness to modify life. Precisely designed pharmaceutical products will be available to treat nearly every disease, often by interrupting them at the molecular level and doing so in ways that match the specific needs of the patient. Stem cells, whether derived from embryos or from patients themselves, will probably be used to regenerate nearly any tissue or cell in the body, perhaps even portions of organs, including the brain. The genes in patients' bodies will be modified, either to correct a genetic anomaly that underlies a disease or to trigger a special response in specific cells to treat a disease or injury. It is more difficult to foresee the full extent of the long-term consequences of biotechnology on nonhuman species, on the ecosystem, on colonies of life beyond Earth, and on the human species itself; estimates vary in the extreme. Some suggest that through these means, human beings will engineer their own biological enhancements, perhaps becoming two or more species.

The prospect of these transformations has evoked various religious responses, and scholars from many traditions have been divided in their assessments. Those who support and endorse biotechnology stress religious duties to heal the sick and feed the hungry. Most hold the view that nature is to be improved, perhaps within limits, and that human beings are authorized to modify the processes of life. Some suggest that creation is not static but progressive, and that human beings are co-creators with God in the achievement of its full promise.

Others believe biotechnology will pervert nature and undermine human existence and its moral basis. They argue, for instance, that genetic modifications of offspring will damage the relationship between parents and children by reducing children to objects, products of technology, and limit their freedom to grow into persons in relationship with others. Some warn that saying yes to biotechnology now will make it impossible to say no in the future. Still others suggest that the point is not to try to stop biotechnology but to learn to live humanely with its powers, and as much as possible to steer it away from selfish or excessive uses and toward compassionate and just ends.

See also CLONING; DARWIN, CHARLES; DNA; EVOLUTION; EUGENICS; GENE PATENTING; GENE THERAPY; GENETICALLY MODIFIED ORGANISMS; GENETIC ENGINEERING; GENETICS; GENETIC TESTING; HUMAN GENOME PROJECT; IN VITRO FERTILIZATION; REPRODUCTIVE TECHNOLOGY; STEM CELL RESEARCH

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RONALD COLE-TURNER

BLACK HOLE

Modern astronomy has produced a theory about the life of stars in which the fate of a star crucially depends on how massive it is. Lighter stars might end as red dwarfs, and heavier stars as enormously dense but tiny neutron stars. The heaviest stars collapse in upon themselves, creating black holes. Black holes are called *black* because the gravitational force associated with them is so strong that no light can escape. The infinite gravitational attraction at the edge of an event horizon such as a black hole not only warps space but also warps time for the hypothetical observer near the black hole.

See also ASTROPHYSICS; COSMOLOGY, PHYSICAL ASPECTS; GRAVITATION; SINGULARITY

MARK WORTHING

BOHR, NIELS

For the first half of the twentieth century, as both physicist and natural philosopher, Niels Bohr was at the epicenter of the quantum revolution that gave physicists their understanding of the atomic structure of matter. Bohr's Institute for Theoretical Physics (now the Niels Bohr Institute) in Copenhagen, Denmark, was the central headquarters of this revolution, and Bohr was its most senior and respected spokesperson. His influence made this city of his birth the namesake for the position defended by supporters of the revolution: the so-called Copenhagen Interpretation, which became the dominant or orthodox understanding of quantum theory, even while remaining controversial and beset with numerous conceptual difficulties. Although the quantum revolution transformed theoretical physics utterly, making a return to the worldview of classical physics out of the question, Bohr's viewpoint never received unanimous acceptance; several of Bohr's peers, most notably Albert Einstein and Erwin Schrödinger, remained critical and designed various paradoxes to confront the party of Copenhagen. From 1927 onwards, Bohr and Einstein debated these issues, but the precise implications of their differing views remain a matter of intense discussion among historians and philosophers of science.

Early life and work

Born in 1885, Niels Bohr, and his younger brother Harald, a famed mathematician, came to maturity in Danish academic circles. Their father, a professor of physiology at the University of Copenhagen, was a close friend of the philosopher-psychologist Harald Høffding (1843–1931). The Bohr brothers were auditors and later participants in the intellectual discussions held in the Bohr home with Høffding and their father's other academic friends. Høffding, an eclectic thinker with a broadly Kantian outlook sympathetic to his friend William James's pragmatism, became Bohr's only formal teacher of philosophy.

After receiving his doctorate in physics from the University of Copenhagen in 1911, Bohr found his way to Manchester, England, where Ernest Rutherford had recently discovered a massive positively charged nucleus at the center of the atomic system. The young physicists surrounding Rutherford were eager to develop a theoretical model of a stable atomic system accounting for the then known evidence of atomic behavior. Starting from the assumption that no classical mechanical model would possibly yield a stable system, Bohr quickly sensed that the secret to atomic stability lay in the quantization of action already postulated in 1900 by the German physicist Max Planck (1853–1947) as a heuristic move toward a formula for black-body radiation consistent with observation.

Bohr's 1913 presentation of his atomic model astonished physicists by deriving the observed frequencies of the spectrum of the simplest atomic system, hydrogen. Bohr assumed two nonclassical postulates. The first proposed that atomic systems exist in a series of discrete "stationary states" in which, contrary to classical electrodynamics, they neither emit nor absorb radiation. The second postulate stipulated that when atomic systems interact with electromagnetic radiation, the energy emitted or absorbed is determined by the difference between the energy of the stationary states in which the system existed before and after the interaction and is a function of the frequency of the radiation. While Bohr used classical mechanical models of electrons orbiting a nucleus to derive the energy of the stationary states, those same classical pictures imply a radically unstable system, a conclusion explicitly denied by Bohr's first postulate. Moreover, in classical physics, the energy exchanged with radiation should be a function of the orbital characteristics of the electron in each stationary state, rather than the *difference* between two states. If one imagined the electron in a spatiotemporal trajectory "jumping" from one quantized stationary state to another, the electron would seemingly have to know to which orbit it was going the moment it departed its original orbit. Thus Bohr's 1913 model already gave the interaction between matter and radiation a *wholeness,* implying that the theoretical representation of such interactions in terms of visualizable, mechanical pictures could not be a realistic picture of microphysical processes.

Complementarity

From 1913 to 1925 Bohr pondered how the classical descriptive concepts were to be used in describing microphenomena while his model became the basis of much new research leading towards building up more complex atomic systems. Although it had many successes, ultimately this "old" quantum theory could not derive the intensities of spectral lines. In 1925 the German physicist Werner Heisenberg (1901–1976) formulated a *matrix mechanics* dispensing altogether with spatiotemporal models of atomic systems by replacing single numbered kinematic and dynamic parameters of position and momentum with matrices. A few months later Erwin Schrödinger (1887–1961) produced *wave mechanics,* generally held to be mathematically equivalent to Heisenberg's theory, though in a more tractable form. After intense discussions with Bohr and Schrödinger, Heisenberg derived the indeterminacy relations in the spring of 1927; that summer Bohr formulated his new "viewpoint" for understanding this quantum description, and named it *complementarity.*

Bohr's viewpoint of complementarity, originally presented in 1927 in Como, Italy, remains obscure and controversial, although he repeated the basic argument in many essays. Bohr argues that the use of concepts rests on presuppositions which, upon extending experience into new domains, may be discovered to be of restricted applicability, thus forcing a "rational generalization of classical physics which would permit the harmonious incorporation of the quantum of action" (1987 [1963], p. 2). The quantization of action introduces a feature of "wholeness inherent in atomic processes, going far beyond the ancient idea of the limited divisibility of matter" (1987, p. 2). Thus a visualizable space-time picture of such interactions is merely a conceptual abstraction used for interpreting phenomena as interactions between microphysical particles and macroscopic observing systems that must be classically described. Measurements are interactions, but this indivisibility of interactions implies that the experimental arrangements required for determining both *kinematic* (space and time) and *dynamic* (momentum and energy) parameters defining a system's state are physically exclusive, although both are required for a complete definition of the system's state. Heisenberg's indeterminacy relations express formally the physical fact that the indivisibility of interaction prohibits defining the state of the system in terms in which both kinematic and dynamic properties have precise values. Classical deterministic predictions were possible because both properties could be predicated of systems only by neglecting the interaction involved in the measurement, but quantum predictions of observables are statistical because the interaction in which a kinematic parameter is well defined excludes the interaction in which a dynamic parameter can be defined.

Classical determinism requiring predication of a mechanical state with simultaneous arbitrarily precise values of kinematic and dynamic parameters now appears as an idealization attainable only in interactions that are enormous compared to the scale of the quantum of action. The paradoxical fact that, for defining the state of both matter and radiation, the system needs to be characterized using both wave and particle "pictures" has misled some interpreters to misread complementarity as a relation between *wave* and *particle* concepts. Classically both kinematic and dynamic measurements can be made in a single experimental arrangement because the effect of the interaction with the measuring system can be left out of the account. Therefore precise values of both position and momentum can be "combined into a consistent picture of the object under investigation" representing its objects as either particles (if matter) or as waves (if radiation). However, because of the wholeness of quantum interactions, Bohr concludes "evidence obtained by different experimental arrangements exhibits a novel kind of complementary relationship . . . which appears contradictory when combination into a single picture is attempted" (1987 [1963], p. 4). Representing the object as a "wave" or a "particle" proves contradictory because defining the state of a material system requires defining the particle's momentum, but in the quantum case to define the particle's momentum one must give it a wavelength, a property defined only by representing it as a wave. To define the state of radiation one must attribute to waves the property of momentum, which requires picturing the object as a particle. Thus *wave-particle dualism* arises from the complementary relation between the phenomena by which measurements of kinematic and dynamic parameters are empirically determined. Bohr held no other conceptual scheme avoiding this complementarity would be possible because to avoid "ambiguity" one must describe the measuring instruments in classical terms. This unambiguity is the foundation for the objectivity of the quantum description; thus Bohr abandons grounding objectivity in an ontological predication of properties of individuals.

Influence beyond physics

Bohr ventured beyond atomic physics to suggest that in other cases where the "analysis and synthesis" of experience encountered indivisible interactions analogous to quantum interactions, one must expect to employ complementary descriptions. In biology the wholeness of the organism-environment interaction necessary for displaying the phenomena of life, excludes the sort of isolation necessary for unambiguously defining the organism's state as a mechanical system, thereby leading to the necessity for a complementary combination of functional descriptions with mechanistic ones. Psychological descriptions of conscious experiences require the well known distinction between *empirical ego* (the object) and the *transcendental ego* (the subject) leading to the complementarity between deterministic description and that employing the notion of free will. In the human sciences Bohr called attention to the complementary relationship between descriptions of experience by persons within a culture or religious tradition and those of observers from another culture standing outside the cultural tradition being described, leading him to speak of different cultures and religious traditions as "complementary."

Bohr has often been presumed to be a positivist holding an antirealist or instrumentalist interpretation of atomic physics; however, his viewpoint arises from a *physical* discovery expressed in the quantization of action rather than an epistemological analysis along positivistic lines. He agrees that quantum physics bars a realistic visualizing of microphysical interactions, but it is clear that he regards atomic systems as independently real entities in nature, not as theoretical constructions. He seeks a radical revision of the conception of physical reality rather than its elimination from atomic physics. Although Bohr emphasized the epistemological lesson following from the indivisibility of observational interactions at the atomic level, he left unexplored the ontological implications of combining complementary descriptions of the same object appearing in different phenomena, thus inviting widely divergent philosophical interpretations of complementarity that continue to be debated.

See also COMPLEMENTARITY; COPENHAGEN INTERPRETATION; DETERMINISM; EINSTEIN, ALBERT; PHYSICS, QUANTUM; WAVE-PARTICLE DUALITY

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HENRY J. FOLSE, JR.

BOTTOM-UP CAUSATION

See UPWARD CAUSATION

BOUNDARY CONDITIONS

Physical laws are characterized by their mathematical form, the values of universal constants, and the contingencies to which the laws apply—known as boundary conditions. For instance, Newton's Law of Universal Gravitation is an inverse square law (its mathematical form), employs the gravitational constant (a universal constant), and applies to certain boundary conditions (like the positions and momentums of the planets at a given time). Boundary conditions, because of their inherent contingency, hamper the physicist's search for a theory of everything. In addition, when the mathematical form of physical laws is nonlinear, as in chaotic systems, slight changes in boundary conditions can lead to enormous changes downstream.

See also COMPLEXITY; CHAOS THEORY

WILLIAM A. DEMBSKI

BUDDHISM

Originating with the life of the historical Buddha, Siddhartha Gautama, born in present-day Nepal in the sixth century B.C.E., varieties of Buddhism have developed and spread across the globe for the past 2,500 years. Though Buddhism by no means presents a uniform face in all cultures and time periods, Buddhist traditions do reveal certain common experiential contours, doctrinal themes, and ritual practices. Speaking experientially, Buddhism emphasizes disciplined introspection through a combination of meditative, recitative, and gestural sequences. Doctrinally, Buddhist teachings call attention to four primary themes: suffering, liberation, emptiness, and interdependence. And in terms of ritual practice, Buddhists engage in a combination of devotional offerings, initiatory rites, and other ceremonies to mark important spiritual and life-cycle transitions.

Buddhist history reflects three primary "vehicles" of Buddhist thought and practice: *Nikāya* (Individual Tradition, of which *Theravāda* Buddhism represents one strand); *Mahāyāna* (Great Vehicle); and *Vajrayāna* (Diamond Vehicle, also known as Tantric Buddhism). However, from a contemporary perspective, it remains difficult to know the extent to which these traditions operated autonomously from one another. It seems likely that a great degree of overlap existed between Buddhist traditions, as, for example, when a practitioner espousing Mahāyāna precepts also may have engaged in Tantric practices. Adherents of all three traditions exist throughout the world, though one traditionally associates Nikāya (primarily Theravāda) Buddhism with Southeast Asia; Mahāyāna Buddhism with historical India, China, and parts of Southeast Asia; and Vajrayāna Buddhism with historical India, Tibet, Japan, and, since the late nineteenth century, the West.

Buddhism concerns itself with science in, for example, its Tantric Vehicle. Tantric Buddhist texts occupy themselves with questions of cosmology, astronomy, embryology, and physiology, and they concisely weave religion and science together into a seamless fabric. An eleventh-century Sanskrit Buddhist Tantric text, the *Śrīlaghu Kālacakratantra* (or *Śrī Kālacakra* [Auspicious short Kālacakra Tantra]), constitutes a primary example of a religious text oriented toward meditative practice that also serves as the repository for highly developed scientific observations of the time. Divided into five chapters, the *Śrī Kālacakra* and its corresponding twelve-thousand-verse *Vimalaprabhātīkā* commentary contain five chapters in both Sanskrit and Tibetan redactions: (1) cosmology, the realm-space section; (2) physiology, the inner-self section; (3) initiation, the empowerment section; (4) generation stage, the practice section; and (5) completion stage, the gnosis section.

More specifically, the first chapter of the *Śrī Kālacakra,* sometimes referred to as *Outer Kālacakra,* presents a cosmological alternative to traditional Buddhist cosmology as articulated in the fourth century in Vasubandhu's *Abhidharmakośa* (Treasury of manifest knowledge) and its *Autocommentary,* the *Abhidharmakośabhāsya.* The second chapter, sometimes referred to as *Inner Kālacakra,* outlines the physiology of the "subtle body" (Sanskrit, *śuksmadeha*), including its structure and function. This chapter also addresses the time cycle of breaths taken by a person during a day. According to this system, the vital-wind processes, which Tantric practitioners seek to control, situate the temporal divisions of the universe in the body. The third to fifth chapters of the *Śrī Kālacakra,* sometimes referred to as *Alternative Kālacakra,* include an explanation of the qualifications necessary for both guru and disciple and also describe the activities that precede empowerment, which include examining the initiation site, accumulating ritual materials, taking control of the site, creating a protective circle, and constructing the *Kālacakra* mandala. This third chapter also describes disciples' progress through the mandala, the guru's conferral of empowerment, and the concluding rituals that follow the empowerment ceremony. The fourth and fifth chapters of the *Śrī Kālacakra* focus on the practice of *Kālacakra's* six-limbed yoga. These practices include both *generation stage* and *completion stage* yogas.

See also BUDDHISM, CONTEMPORARY ISSUES IN SCIENCE AND RELIGION; BUDDHISM, HISTORY OF SCIENCE AND RELIGION

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JENSINE ANDRESEN

BUDDHISM, CONTEMPORARY ISSUES IN SCIENCE AND RELIGION

Buddhist reflections on science are based on insights, doctrines, and practices that have evolved from the teachings and life of Siddhartha Gautama (c. 563–486 B.C.E.), the founder of Buddhism. The assumption that reality is in constant flux, together with the principle of *pratītyasamutpāda* (dependent co-arising or interdependence), the primacy of mind, and a holistic appreciation of health and the world, are a few of the ideas from which Buddhists have understood and critiqued science, its methods, and its conclusions. *Pratītyasamutpāda* articulates the Buddha's Weltanschauung and is the basis for his teachings. The subsequent development of Buddhist thought and practice explores different facets of this insight.

Pratītyasamutpāda and science

A compound of *pratitya* (meaning "based on" or "dependent on") and *samutpada* (meaning "to spring up together"), *pratītyasamutpāda* affirms the temporal efficacy between a cause and its result. This efficacy underlies the belief in karmic retribution and reward. The principle also recognizes the importance of conditions or indirect causes in generating a result; and explains the origin, persistence, disintegration, and disappearance of existents. *Pratītyasamutpāda* further asserts the formal and spatial reciprocity of all existents. This reciprocity pertains not just to physical entities but also mind (or cognition) and apprehended object. Mind and object are both the cause and the result of the other's existence.

Most Buddhists are open to the discoveries and theories of science, and they seek common ground between the findings of modern science and Buddhist doctrines and beliefs. Thus, though Darwinism met great resistance in the West, the Japanese, for example, deeply ingrained in the Buddhist acceptance of transience, found no difficulty with the concept that humans evolved from lesser forms of life. Transcience is an indisputable thesis for Buddhists. Buddhists examine in great detail the process of change, its phases and their duration, and its practical consequences.

The flowering of Buddhism in the West coincided with the interest in science that emerged from the post-Darwinian need to ground religious belief in new scientific understanding of reality. Moreover, Buddhists understand that objects and individuals are comprised of an ever-changing composite of elements of reality called *dharmas*. Originally dharma referred to social norms and responsibilities. Buddhists broadened its usage to mean the Good, Truth, Teaching, and Law. Dharma (meaning, literally, "thing") is peculiar to Buddhism and in early Buddhism designated the enduring building blocks of transient phenomena. This was an assertion that later, Mahāyān thinkers, came to dismiss. Dharma also refers to mind and its cognitive functions. Although distinct and irreducible, dharmas relate to other dharmas in time and space. The consideration of the momentary spatial and temporal intersection of dharmas prompted Chinese Buddists to further expand the meaning of dharma to include the notion of "event."

The Buddha left a legacy of "benevolent skepticism" of the unproven, an appreciation for relative values, and an empirico-rational problem solving method. As such, Buddhist "truths" are to be discarded if and when they are no longer beneficial. However, investigations into mind and the natural world are not ends in themselves, but are pursued for the purpose of relieving suffering, and many Asian Buddhists are troubled by certain advances of the biological sciences, such as cloning and organ transplant, that challenge traditional views of life, death, and family lineage.

Beliefs and doctrine

Siddhartha Gautama began his spiritual journey with the question of human suffering. After six years of spiritual exercises Gautama realized the Dharma, the truth of *pratītyasamutpāda,* and became the Buddha, which means "Enlightened One." Buddha awakened to the reality that all things, beings, and events, are mutually dependent and irrevocably interrelated. *Pratītyasamutpāda* can be understood as a further development of the law of karma. Karma, literally "action" by living beings, explains the creation, persistence, and disintegration of the universe (*loka-dhātu*). Later, the *Avatamsaka sūtra* and other Mahāyāna Buddhist documents, which emerged in the first and second century, claimed that the universe is a creation and projection of mind. Existentially, karma accounts for an individual's present life situation, which was determined by the moral quality that his or her actions generated in the past. Similarly, deeds performed in one's present life determine one's station in the next.

Mahayana Buddhists accepted the early Buddhist understanding of the temporal efficacy of karma, but proceeded to expand *pratītyasamutpāda* to describe the formal and spatial relationship between and among dharmas. The relationship of a single dharma with the world, as well as with every other dharma, is outlined by the doctrine of *fajie yuanqi* (universal *pratītyasamutpāda*). In a mutually dependent world, each dharma assists in the creation and support of the world and every other dharma. At the same time, each dharma is supported by all other dharmas.

Fazang (643–712), the third patriarch of the Chinese Huayen school, detailed the temporal and spatial relationships among all dharmas with the "Ten Subtle Principles of the Unimpeded Fusion of *Pratītyasamutpāda,*" which is discussed in his *Huayen tanxuanji,* a commentary on the *Huayenching* (*Avatamsaka sūtra*). The Ten Principles describe the relationship between each dharma and every other dharma. Similarly, an individual is never conceptualized in isolation, but as part of a dynamic and ever-evolving society of other persons and the universe. Morally, *pratītyasamutpāda* engenders the virtues of responsibility and gratitude. More concretely, this vision of interdependence is true for the human person. Health is understood to be a balance among all the bodily functions and an integration of body and mind. The health of the individual is intimately linked with the health of society and the environment. While Buddhists are primarily interested in karma and *pratītyasamutpāda* as a principle of moral and spiritual causality, these notions are also used to explain the formation of and interactions in the physical and cognitive worlds.

Though Theravada and Mahayana Buddhists differ in their understanding of *pratītyasamutpāda,* they agree that change is the nature of reality, that suffering is endemic to the human condition, and that the realization of *Nirvana* results in the transcendence of change and suffering. Both traditions accept *anātman* (selflessness), a notion that the Buddha reasoned reflected the reality of the constantly changing relationships among the five *skandhas* (aggregates)—i.e., form, sensation, perception, mental formations, and consciousness—that constitute the psychological self. The *skandhas* are not substantial or eternally existing forms. The Buddha never denied there was an ontological self.

Theravada, the representative tradition of present-day South and Southeast Asia, and Sarvastivada, a once influential non-Mahayana school, further refined these five *skandhas* into seventy-five dharmas, or ontological elements of reality. Yogacara, a Mahayana tradition, lists a hundred dharmas. Systematic summarizations of these dharmas and their causal relationships are articulated by the fifth-century Theravadin master Buddhghosa in the *Visuddhimagga,* and by Vasubandhu (c. 400–480), a Sarvastivada apologist, in the *Abhidharmakośaśāstra.* In contrast, Mahayana, which represents the tradition of present day North and East Asia, proposed a more radical view, namely that dharmas themselves are devoid of essential essence. This view is proclaimed in the *Prajñaparamita-sutra* (*Heart Sutra*): Form is emptiness and emptiness is form.

Attitudes toward science

Assessment of the scientific method. Buddhists do not reject the efficacy and benefits of science; they nonetheless critique the scientific method and the validity of the knowledge that is derived from science. Appealing to the *Abhidharmakośaśāstra's* classification of four conditions, Izumi Yoshiharu faults the narrowness of observation employed by the scientific method to explain the appearance of an event. The *Abhidharmakósaśāstra,* which enumerates, in addition to the four conditions, six causes and five results, states in sum that the occurrence of an event is facilitated by dominant causes and contributory conditions. A dominant cause directly contributes to the fruition of a karmic event. For example, an acorn would be the dominant or direct cause of an oak tree because only an acorn can become an oak tree. Contributory conditions include sunlight and soil conditions, as well as adequate rainfall to nurture and sustain the acorn as it transforms from a sprout to a sapling and into a mature tree. Both causes and conditions are necessary for an event or being to appear. In addition, the *Abhidharmakósaśāstra* cites the necessity of passively efficacious karmic causes and conditions that do not prevent or hinder the occurrence of a result. For example, the violets in a garden have no direct relationship to the phases of the moon, but in so far as their blossoms do not prevent its rotation, they are considered causal conditions. The *Visuddhimagga,* which lists twelve kinds of karma into three categories, details a similar understanding.

Buddhists also question the validity of objective observation, which presumes an unchanging observer and phenomenon, since reality—things and beings—are in constant flux. Not only does an observer continually change, but different observers will observe the same phenomena differently. Further, Buddhists have determined through their meditative exercises that perception determines the way objects and events seem to exist. Taking their cue from such documents as the *Avatamsaka sūtra* and *Prajñāsāmadhi sūtra,* Buddhist thinkers such as Maitreya (c. 270–350), Asanga (c. 310–390), Vasubandu, and others from the Yogācāra tradition argued that the reality one perceives and knows is a transformation of one's mind. When a person sees a red rose, what the mind perceives are neural signals that have been converted from light waves that strike the retina of the eyes. Subsequently, the mind interprets and cognizes these signals. Buddhists do not deny the reality of the physical world. Additionally, one's moods and temperament, as well as one's physical and environmental conditions, influence how one sees the world. Perception varies from moment to moment and differs from person to person.

This mutuality between the observer and observed preoccupied early Buddhist and Yogācāra thinkers who explored in great detail the mutuality of mind and its object of perception. In the twentieth century, the German physicist Werner Heisenberg arrived at a similar conclusion in quantum physics. The Heisenberg Uncertainty Principle claims that on the subatomic level, one cannot know simultaneously with precision the velocity and position of an entity. The observer changes the very nature of the "reality" that is being measured.

The Buddhist doctrine of *pratītysamutpāda* also challenges the validity of scientific principles or any other paradigm as the arbitrator of truth. Science and its method survey only a limited spectrum of reality experienced by human beings. *Pratītysamutpāda,* which recognizes the importance of every dharma, validates multiple centers and shifting paradigms. The tenth of Fazang's Ten Principles, the principle of complete accommodation of principal and secondary dharmas, (*zhuban yuanming jude men*) describes the rationale for shifting paradigms. In an interdependent world, all dharmas are mutually supportive and mutually dependent. When a dharma is singled out, it becomes the principal dharma, and the remaining dharmas are relegated to a secondary status. Every dharma has the potential of alternately assuming the principal or secondary role. On a given occasion, a dharma may be the principal; on another, a second dharma may assume the principal role.

This idea of the shifting perspectives of an event is illustrated by Japanese director Akira Kurosawa's film *Rashomon* (1950). The "truth" is relative to a particular storyteller: the murdered samurai who speaks through a medium, his violated wife, the bandit, and the woodcutter who witnessed the event. Each retelling emphasizes the storyteller's version, while relegating other perspectives to a secondary role. To be truly objective, one must see an event from all possible vantage points. Shifting vantage points offer alternative perspectives of reality. One never fully discovers the nature of reality, which may remain forever ambiguous. Scientific paradigms, as Thomas Kuhn argued in his 1962 book *The Structure of Scientific Revolutions,* are forever shifting and riddled with unexamined prejudices and presumptions. Science, which is a visual rendering technique perfected during the European Renaissance, sees a view from a single-fixed point, and, as such, it is hardly objective. As early as the third century B.C.E., Nāgājuna (c. 150–250 B.C.E., one of the primary thinker of Mahāyāna Buddhism and founder of the Madhyamaka school, had already established that all conceptual categories of understanding distort reality.

Environmental science. Buddhism shares a holistic paradigm of nature with the environmental sciences. The doctrine of *pratīitysamutpāda* sees the world as a single whole in which sentient life and the world that supports it are irrevocably intertwined. Buddhist "teachings emphasize the importance of coexisting with nature, rather than conquering it. . . . The very core of Buddhism evolves around compassion, encouraging a better respect for and tolerance of every human being and living thing sharing the planet" (Kabilsingh, p, 8). Mary Evelyn Tucker and Duncan Williams's *Buddhism and Ecology: The Interconnection of Dharma and Deeds,* a collection of papers presented at the 1996 proceedings of Earth Charter, set forth the Buddhist vision of ethical principles concerning the environment for the twenty-first century.

Organ transplant. Buddhist reflections of biotechnological advances such as gene therapy, cloning, and organ transplants, which have pushed the traditional boundaries of life, death, and personal identity, are grounded on the meaning of sentience and life. Buddhist medical theory is based on presuppositions of transience, the composite nature of persons, and a holistic understanding of the individual. Buddhists understand human life to be a fortuitous event that involves the coming together of innumerable causes and conditions. Death is the dissolution of the temporary coalescing of mind and body. Life is identified with sentience, which includes feelings and in its broadest sense encompasses animals, plants, and inanimate objects.

Like *Āyurveda,* the classic system of Indian medicine, on which it is based, Buddhist medicine assumes that the living body consists of a substratum of three humoral fluids—phlegm, bile, and wind—that circulate throughout interconnected channels of the body to ensure vital life functions. Health constitutes the proper balance and circulation of these humors. Buddhists learned long ago that a healthy body is required before one can discipline the mind for spiritual exercises. Buddhists have identified life with cardiopulmonary activity. Consequently, the absence of brain activity, the criterion used for organ transplants, does not necessarily signify the death of the person. Many Buddhists are of the opinion that as long as the body is warm, there is life, and they have resisted the harvesting of organs. Additionally, some think that a body, though cold, may feel pain when incisions are made to remove its organs.

Another pervasive attitude against organ transplants is the belief that life is impermanent and death is inevitable. Such efforts to extend life disrupt an individual's karmic life span. Moreover, organ transplants are possible only at the expense of another person's life, a violation of the precept to abstain from taking and profiting from another life. Consequently, some Buddhists advocate the development and use of artificial organs. However, those who favor transplants argue that the gift of life is the greatest gift an individual can give.

While Buddhist doctrine offers ample support for the reluctance of organ transplants among East Asian Buddhists, the Confucian notion of filial piety, which has been incorporated into their ritual and socio-cultural practices, is also influential. The opening lines of the Confucian text *Hsiao Ching* (Classic on filiality) states, "Filial piety is the basis of virtue and the source of our teachings. We receive our body, our hair, and skin from our parents, and we dare not destroy them." Chinese funerary practices insist that a person should be buried with every part of his or her body. Such reasoning sees the donation of one's organs to be an unfilial act. Receiving the heart of another person raises questions of family identity. The Japanese reluctance against organ transplants and organ donation is rooted in a pre-Buddhist notion of personhood, which holds that physical death marks the beginning of the spiritual life of a person. The spirit can mature or proceed to ancestorhood only if the body is interred with all of it parts.

Cloning. As of 2002, Buddhist reflections on cloning and genetic engineering have been few and mostly cautionary. Citing the sanctity of life, some Buddhists are concerned over the unforeseen consequences that biotechnology will have on human life and the environment. Others find repugnant the idea of cloning a human being to produce organs for use in transplantation. However, invoking the Buddhist assumption that reality is in constant flux, the birth of Dolly, the first successfully cloned sheep, as well as the prospect of a human clone, are part of evolving reality. The birth of Dolly also raises issues of the continuity of family lineage. Genetic manipulation brings into question the relationship between prior generations, their progeny, and future generations.

Cognitive sciences. Buddhists have expended great energy in investigating and speculating on the nature of mind and cognitive functions. Psycho-spiritual phenomena experienced during meditative practice are the basis for the speculations and systemization of mind, mental functions, and the world. Further, the belief in successive rebirths means that mind is not an emergent property of life, but is one of the conditions for it. Thus the Buddhist would say, "I am, therefore I think." Invoking the theory of karma and the idea of successive lives, the energy of consciousness from a previous being is a necessary condition for the arising and development of life in the womb.

For the Yogācārins, mind and object (psychic impressions of the objective world) arise together. Since the mid 1970s, there has been a heightened interest in Buddhism and the neurosciences by academics in the West. The Dalai Lama and a number of neurologists, biologists, psychiatrists, physicists, and philosophers have organized "Mind and Life" meetings centering on the nature of mind. One result of these discussions was the publication of *The Embodied Mind* (1991) by Francisco J. Varela, Evan Thompson, and Eleanor Rosch. They explore the structure of the subjective experience through cybernetics, brain science, psychology, and artificial intelligence using Tibetan Abhidharma categories of mind and mental functions. James H. Austin's *Zen and the Brain* (1998) weaves brain research with his Zen experiences.

Conclusion

Buddhism's interest in science is essentially therapeutic—to relieve human suffering and to care for the earth. Though Buddhists are open to the discoveries of change, Asian Buddhists were almost universally wary of improper use of new knowledge, and thus have been preoccupied with the ethical issues generated by organ transplant and cloning. In contrast, Western scholars and Western converts to Buddhism tended to explore the implications of Buddhist ideas. Finally, different systems of knowledge are built on differing assumptions of reality, which in turn lead to different notions of reality and categories of understanding. For the Buddhist, Western science and its assumptions are just one of many ways of understanding reality. Most Buddhists, while acknowledging the scientific and technological domination of the West, continue to find correspondence and derive legitimacy for their vision of reality. Perhaps, as Izumi suggests, a science based on the complex notions of causality of the *Abhidharmakośaśāstra* might lead to alternative methods of observation, experimentation, and theories of reality (Izumi 1999, p. 63). An alternative science and methodology, for example, can perhaps be extrapolated from currently practiced Tibetan Buddhist medicine, which still preserves much of its original paradigm.

See also BIOTECHNOLOGY; CLONING; CYBERNETICS; DARWIN, CHARLES; ECOLOGY; EXPERIENCE, RELIGIOUS: COGNITIVE AND NEUROPHYSIOLOGICAL ASPECTS; GENE THERAPY; HEISENBERG'S UNCERTAINTY PRINCIPLE; KARMA; NEUROSCIENCES; PARADIGMS; QUANTUM FIELD THEORY

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RONALD Y. NAKASONE

BUDDHISM, HISTORY OF SCIENCE AND RELIGION

The fundamental Buddhist ideas of interdependence and impermanence are based on a rational apprehension of the world that can be likened to the modern scientific method. Because of this basic shared approach, Buddhism and science doe not come into serious conflict. The primary concern of Buddhism is to relieve human spiritual suffering and not to clarify the laws of nature. Thus Buddhists have freely adopted the practical scientific technologies of each epoch and place. For Buddhists, scientific technology is neither good nor evil. However, Buddhism recognizes that a self-centered application of technology can harm the integrity of other life forms, and hard to these can in turn harm human beings. Buddhism emphasizes the holistic relationship of life and the harmonious coexistence of all beings and all things.

Essence of Buddhism

Buddhism was founded in northernwestern India by Gautama Buddha (463–383 B.C.E.), who realized the truth of *Pratītya-samutpāda* (interdependent co-arising). For Buddhists, *interdependence* means that all living beings are born through the intersection of causes and conditions, and all lives are supported by the existence of others. The term conveys two meanings. First, interdependence is a fundamental principle of universe. Though the world is full of distinctions, each being exists and evolves in harmony with the vast network of interdependence that sustains all life. The world is an interconnected, interdynamic, cooperative whole, not a collection of separate, oppositional parts. Buddhists understand that no being is unconditional, permanently fixed, or immutable. Nothing exists by itself. Second, interdependence is not a mechanical law of nature but is the reality of compassionate relationships. Awakening to interdependence cultivates a sense of consideration towards all beings. All beings are worthy of respect due to their mutuality. Each being is an irreplaceable existence of the universe. Buddhism teaches one how to see all sentient beings as fellow living beings and cultivate the empathic mind of oneness with others. In the *Sutta-nipata,* one of the oldest Buddhist scriptures, the Buddha discusses his view toward life as follows:

> Whatever living beings there be: feeble or strong, tall, stout or medium, short, small or large, without exception; seen or unseen, those dwelling far or near, those who are born or those who are to be born, may all beings be happy. Just as a mother would protect her only child at the risk of

> her own life, even so, let him cultivate a boundless heart towards all beings. Just as a mother would protect her only child at the risk of her own life, even so, let him cultivate a boundless heart towards all beings. (*The Sutta-nipata,* p. 16)

The Buddha, according to this passage, everywhere and at all times respected all beings equally, without discrimination, and wished them happiness. Therefore, human beings should be aware of the truth of coexisting with other life forms through mutual support and should cultivate compassion toward other beings. The ultimate goal of Buddhist is to save both the self and others.

The relationship between Buddhism and science

Historically, Buddhists have placed highest value on a supermundane wisdom that is beyond secular attachments and have encouraged compassionate acts toward all living beings. For Buddhists, there was no need to take part in practices such as sacrificial rituals, divination, or astrology, which have been popular in the societies of the various countries Buddhism has entered. The natural sciences also never became a significant part of Buddhist practice, although Buddhists were eager to introduce into their practices the knowledge of medicine and pharmacology, as well as more practical scientific technologies from paper and ink making to metallurgy, sculpture, and architecture. Such practical knowledge provided them with advanced skills in building temples, carving and casting statues, and printing scriptures, all of which helped in spreading the teaching of Buddhism. It is well known that the concepts of zero and fractions were first discovered in India. The discovery of zero is considered to be related to the Buddhist concept of impermanence or *anatman* (no-self).

Science focuses on the external world and seeks to analyze objectively the phenomena of the universe, including human beings, to clarify the principle behind each phenomenon and to apply its discoveries to society to bring comfort to human lives. On the other hand, Buddhist teaching focuses mainly on the inner self as it faces the reality of suffering. The Buddhist path aims at pinpointing and eradicating causes of suffering for the sake of the accomplishment of the totality of the individual human being and that being's peace of mind. Therefore, Buddhism, which focuses on the individual, did not develop a standpoint of observing the universe and natural phenomena objectively, and Buddhism did not attempt to formulate a mechanical model of the universe.

Buddhist cosmology is based on the concept that nature and human beings are not mutually opposing, but are harmoniously interdependent. Therefore, nature, or the external world, has never been considered as merely material existence within the cosmology of Buddhism. One of the most representative descriptions of the Buddhist cosmology appears in the *Abhidhaemakosabhasya* composed during the fifth century C.E. by Vasuvandhu, which states that at the foundation of the universe a vast ring of wind floats within empty space. The thickness of the ring is 1,600,000 *yojana* (one *yojana* is approximately seven miles) and its circumference is 1059 *yojanas*. Above the ring of wind there is a ring of water, and on the top of the water ring is a ring of metal. There is a layer of water, an ocean, above the metal ring. At the center of the ocean is a mountain named Sumeru. The height of the mountain is eighty thousand *yojanas*. Mount Sumeru is surrounded by nine mountain ranges and eight oceans, and the sun and moon circle around it. This is the world of the six realms of transmigration known as *samsara*.

The world of the six realms of transmigration consists of hell (*naraka*), the realm of hungry ghosts (*preta*), the realm of beasts (*tiryand*: the realm in which beasts kill each other), the realm of human beings (*manusa*: although humans are in the state of suffering, they have self awareness of their state of impermanence and ignorance and are capable of seeking the true living), the realm of titans (*asura*: deities of anger and fighting), and the realm of heavenly beings (*devas*). These six realms are all the world of suffering.

Until modern Western scientific theories describing the shape of the Earth and the structure of the solar system were introduced into Buddhist nations like India, China, and Japan, the majority of Buddhists believed that this cosmology truly represented the structure of the universe. However, Buddhist cosmology was not created as a chart of the Earth discovered through geographic survey or astronomical observation. Rather, Buddhist cosmology was a vision created spiritually by Indian Buddhist monks, both Theravada and Mahayana, who contemplated upon the towering Himalayan mountains in the north of the subcontinent. The purpose of this cosmological vision is to reveal the reality of this world, which is filled with defilements and sufferings as living beings transmigrate through the six realms of existence.

Buddhists meditate upon the concept of transmigration of the six realms of existence in order to awaken to truths of impermanence and vanity and to achieve the state of enlightenment, which is beyond the realms of ignorance. Even today, this spiritual cosmology of Buddhism remains respected within Buddhist communities throughout Southeast and East Asia.

India. The *Ayurveda,* a traditional Indian book on medicine that was adopted by Buddhism, discusses surgery, pediatrics, toxicology, and divine pharmacology. It even includes a skeletal chart of the human body. The Buddha is often referred to in Buddhist documents as the "Great and Good Physician" and "Great Doctor King." The Buddha's teaching is regarded as a kind of medicine that relieves human suffering and brings spiritual liberation. In the *Anguttara-nikaya,* the Buddha declared, "Caring for the ill is no different from caring for me." One who cares for a dying person, through that act of caring, reciprocally learns about the impermanence and preciousness of life. From the time of early Buddhism, and through the history of the religion in China and Japan, there have continually been movements to provide care compassionately to the sick.

During the third century B.C.E., King Asoka of the Mauryan Empire, after reflecting on the cruelty and evil of war, converted to the teaching of the Buddha, which taught compassion and peace. Based on Buddhism's egalitarian view of the original nature of all human beings, the king protected all religious traditions equally. He built hospitals for humans and animals, grew medicinal herbs, planted trees on the streets, and dug wells and ponds for the well-being of the people.

In the beginning of the second century C.E., during the reign of King Kaniska of the Kusana Empire, the royal physician Caraka, an ethicist and a Buddhist, compiled a great book on medicine. According to the book *Caraka-Samhita: The Collected Medical Treatments of Charaka,* human beings must strive to seek three goals: to respect all lives, to obtain fulfilled lives, and to attain the happiness of enlightenment. In India, the practice of medicine was not an independent area of science, but was treated as an integrated part of Buddhism, philosophy, and ethics.

China and South East Asia. Numerous Mahayana and Theravada Buddhist scriptures dealing with the cure of general illnesses, eye maladies, and dental problems appear from about the late fourth century C.E., when advances in medicine and pharmacology were made. In Tibet, China, and South East Asia, the study of medicine and pharmacology was based on traditional Indian *ayurvedic* medicine. Additionally, in China Buddhists incorporated existing traditional medical practices including acupuncture, moxibustion (moxa-herb combustion treatment), and medicinal herbs to cure illnesses.

During the Tang dynasty, Chinese Buddhism reached its maturity in part through cultural exchanges with regions to the west. During the early eighth century, the monk Yixing (683–727), famous as an astronomer and mathematician in the capital city Changan, created the Tayan calendar at the request of the emperor Xuanzong in 727. An accurate calendar was essential because it was believed that the movements of the stars and planets had a great influence on the prosperity of the empire. The Tayan calendar was based on the existing Chinese calendar system but enhanced its accuracy through the use of astronomical observations. It remained the basis for calendar making for many centuries thereafter. The Tayan calendar was introduced to Japan in the seventh century and was used as the official calendar for almost one hundred years between the eighth and ninth centuries.

Korea and Japan. Many Buddhist monks from the Korean peninsula traveled to India and China to seek the true Buddhism. Others went to Japan to propagate and establish the foundations of Buddhism in this neighboring country. These monks greatly contributed to the creation of Japanese culture. For example, Huici, a Korean monk from Koguryo, went to Japan in 595 C.E. and was appointed the tutor of Prince Shotoku. In 602, the monk Guanle from Pekche introduced the studies of astronomy, geography, calendar making, and mathematics. In 610, Tanzheng, a Korean monk from Koguryo introduced the Chinese technologies and arts of painting, paper making, and ink production. These technologies were also transmitted to nations to the west as Chinese and Korean monks traveled to propagate Buddhism.

In Japan, Prince Shotoku, who studied the Buddhism and politics of the Chinese Sui Dynasty, is credited with introducing new Chinese architectural technology and encouraging the arts of paper and ink making during the seventh century. He built Buddhist temples for the sake of world peace and social equality. In the eighth century the Empress Komyo, influenced by the compassionate spirit of the Tang Dynasty, built the Hiden-in, a "house of compassion" with social welfare facilities providing shelters for the poor, sick, and orphaned, and the Seyaku-in, a "house of medicine" with its own medicinal herb garden and pharmacy offering free care and medicine for the poor. The world's oldest printed materials were Buddhist scriptures found in Korea and Japan. These include *Hyakumantou-darani,* Buddhist scriptures enshrined in three-story wooden *stupas,* which were made to pay tribute to the war dead in 764.

In Japan, physician-monks appear as early as the seventh century. Although these monks bore the title *zenji* (meditation master), they were not advanced *zazen* practitioners but medical care givers for emperors and aristocrats. The work of physician-monks included the techniques of acupuncture and moxibustion, the creation of medicinal compounds, surgery, internal medicine, pediatrics, ophthalmology, and obstetrics. They did not use the practices of esoteric Buddhism, such as mystical prayers and divination, for curing sickness.

From the seventh to twelfth centuries, monks from China, such as Ganjin, and Japanese monks who had studied in China, such as Saicho and Kukai, continued to introduce medical practices, including new medications and breathing exercises. Records indicate that monks in the Nara area—like Kiogan of Todaiji, Kikogan of Toshodaiji, and Hoshintan of Saidaiji—produced and marketed medicine to support the temple economy. During the thirteenth century, the Tendai School on Mount Hiei established a department of medicine within the monastic complex. From the sixteenth century, Jodo Shinshu temples in particular encouraged the production of medicine by popular medical practitioners and donated medicine for the sick.

During the 1920s, the work-oriented Morita therapy was developed within Japanese psychiatric medicine. Based on the teachings of Zen Buddhism, especially the concept of nonattachment, Morita therapy teaches that the more one tries to eliminate suffering, the more suffering becomes fixed in one's consciousness. Morita therapy involves giving up the attachment to suffering by living with suffering while doing physical work, nurturing the mind, and searching for a new and meaningful way to live. Morita therapy clearly contrasts with modern medical practices, which objectify illness as an enemy to be forcefully conquered.

In the 1980s the modern *vihara* movement in Japan, Korea, and Taiwan was created through the teamwork of specialists in Buddhism, medical care, and social welfare. The word *vihara* has several meanings: a temple (*shoja*) or a monastery (*soin*), peace of body and mind, a place for practicing asceticism, and a place for rest or a hospital. Learning from the spirit of hospice care developed by Christians, the *vihara* movement created a network of caregivers and facilities to provide humane and whole-hearted support for patients and their families. The aspiration of *vihara* is that patients and families are not left alone while they are under medical attention. The *vihara* movement, in accordance with the thought of the Japanese Buddhist cleric Shinran (1173–1262), does not aim to control people's minds to make them peaceful at the end of their lives. Nor does it judge people by the manner in which they die. The *vihara* movement accepts each person's death as a unique individual death. People shed tears in memory of the loved one after they are separated from them. The *vihara* movement is also important for the surviving family to learn from the memories of the deceased as guidance for their lives.

Historically, pharmacological research and the production of traditional medicines developed in areas in which the practice of Buddhism was strong. Buddhists did not believe that prayer cured sickness, nor did they give themselves up easily to illness as their unavoidable fate. Instead, Buddhists understood illness to result from causes and conditions, and they directly sought its eradication through the development of medications and treatments.

Tibet. In Tibetan Buddhism, natural science, medicine, and pharmacology are incorporated within Buddhist practice. Tibetan medicine is highly holistic. It emphasizes the integrated mind and body and their harmony with the entire universe. *Gyu-shi* (four medical texts) written in the eighth century is one of the world's oldest documents on psychiatry.

At a Tibetan Buddhist hospital housed in a four-story modern building in downtown Lhasa, doctors who have also studied modern western medicine treat patients according to traditional Tibetan Buddhist medical practice. They consult charts of human anatomy showing the paths of respiratory tracts, arteries, and chi; charts of pressure points in the human body; and charts of plants and animals used for food. Buddhist doctors in Lhasa also use charts explaining how to diagnose illness by analyzing urine and blood, and they refer to *tanka* paintings of astronomical charts. This combination of charts represents the fundamental Tibetan Buddhist concept of the interrelatedness of the human body and the universe. This hospital is also attempting to compile a scientific analysis of the psychology of Buddhist enlightenment through modern psychology.

Buddhist encounters with modern Western science

When modern western science was first introduced to countries with large Buddhist populations, no major conflicts arose. Buddhists accepted western scientific technologies without much resistance. For example, in Japan during the nineteenth century, there emerged an idea of Japanese spirit and Western knowledge (*wakon yosai*), which entailed the introduction of Western knowledge and technology with respect to traditional Japanese spirituality.

Asian society through the twentieth century has never experienced a drastic transformation of worldview to parallel the European scientific revolution or the Renaissance. One explanation for this is that Asian religions do not posit a singular god that governs over human beings. In the West, however, distinctions of self and others, human beings and nature, and human beings and God are clear. Galileo Galilei's (1564–1642) mathematical vision of the universe and René Descartes's (1596–1650) dualistic distinction of matter and spirit became the foundation for the eventual emergence of advanced scientific technologies such as electronics and genetic engineering. Observing a phenomenon objectively to discover the principles of the phenomenon is the starting point of modern science. For Buddhists, however, there exists no absolute being, and Buddhists need to nurture a sense of harmony and oneness with all things and beings. Humanity and nature are both precious existences, and the universe is composed of mutual supports for each existence. Therefore, modern scientific thinking, which analyzes nature and the universe as material, did not emerge.

Another reason that the modern scientific worldview was readily accepted in Buddhist nations is that Buddhism and science are both founded on the idea that everything in the universe has a cause. The Buddhist truth of interdependent co-arising is the concept that all phenomena are produced by the interrelatedness of things. Modern science also tries to clarify the cause of phenomena by the interrelatedness of matter. Because both Buddhism and science share this kind of rational thinking, Buddhists could easily accept modern science.

However, in Buddhism, understanding phenomena objectively by dividing self from others is considered to be an insufficient partial knowledge that will not bring a holistic understanding of the world. For example, there is a Buddhist analogy of "four visions of one water." For human beings, water is for drinking; for fish, water is a dwelling; for hungry ghosts (*preta*), water looks like a pool of pus; and for heavenly beings (*deva*), water is a beautiful jewel like lapis lazuli. This analogy demonstrates how all beings understand the water in different ways according to their own standpoints. For Buddhists, the existence of beings is not permanently static. Scientific knowledge discovered that a molecular of water consists of oxygen and hydrogen atoms. But this scientific view, while a type of knowledge, by no means captures the true quality of water. In the desert, water is as sweet as honey; for a person washed away by a flood, water is a threat. Buddhism teaches that there can be no understanding of the true quality of existence through attachment to a single viewpoint. Buddhism respects the unity of self and others by going beyond attachment to oneself and one's own perspective.

The Buddhist way of understanding phenomena is perhaps best described by the concept of the four wisdoms of the *Yogacara* school of Mahayana Buddhism. First, the wisdom of the perfect mirror is the wisdom of understanding all phenomena as they are, as if reflected in a clear mirror. Second, the wisdom of equality is the wisdom of understanding the fundamental nature shared by everything that exists. Third, the wisdom of wondrous observation is the wisdom of understanding all existences by their differences through the observation of the characteristics of each existence. Fourth, the wisdom of accomplishing what is to be done is the wisdom of qualitatively transforming the five human senses (touch, sound, sight, smell, taste) so as to act for the benefit and to perfect the existences of all living beings.

Buddhism and science in the twenty-first century

The relationship between science and Buddhism is not contradictory, for each can mutually understand the knowledge and wisdom of the other and bring benefits to humans and the Earth. But Buddhism teaches that people must avoid an extreme dependency on scientific technology because the application of technology has both beneficial and dangerous aspects. In this sense, Buddhists believe that it is necessary to bring a certain degree of regulation into the progress of science.

In order to nurture a productive relationship between Buddhism and science, three important attitudes should be maintained. First, there must be a transformation of viewpoint from self-centered interests to a universal vision. Second, people must respect the values of modern science, yet avoid reducing all existences to material or mathematical formulae. Third, people must stop simply discussing problems and start acting to protect living beings and the environment.

In 1989, the 14th Dalai Lama of Tibet discussed his idea of the relationship between Buddhism and science when he accepted the Nobel Peace Prize. The problems people face today, such as violent conflicts, destruction of nature, poverty, hunger, and so on, are human-created problems that can be resolved through human effort, understanding, and a sense of brotherhood and sisterhood. The Dalai Lama stated that people need to cultivate a universal responsibility for one another and the planet. Buddhists and the spiritual leaders of many other religions support the Dalai Lama's vision. Buddhists believe that people should not negate science simply by pointing out the harms created by modern science. Rather, scientists and religious leaders need to make more efforts to cooperate and depend on each other to bring happiness to Earth and humans.

See also BUDHISM; CHINESE RELIGIONS AND SCIENCE; TRANSMIGRATION

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NAOKI NABESHIMA

BUTTERFLY EFFECT

Butterfly Effect is a term coined by the American metereologist Edward Lorenz (b. 1917) to describe a special effect in chaos theory. Because of the iterative character of chaos theory, the slightest change in the initial conditions of a chaotic system can accumulate in the long run into an enormous effect. Because of this sensitivity to initial conditions, the state of a chaotic system is practically unpredictable in the long run, even though such systems are deterministic. Lorenz came up with a fanciful image to illustrate this effect: The flapping of a butterfly's wing in the Amazon can result in a tornado in China. Thus, the sensitivity of chaotic systems to initial conditions came to be called the Butterfly Effect.

See also CHAOS THEORY; UNPREDICTABILITY

WOLFGANG ACHTNER

C

CALVINISM

The term *Calvinism* was originally a polemical label meant to denigrate those deemed to be followers of the French reformer John Calvin (1509–1564). Those who in fact were most influenced by Calvin chose not to be named after a person—Calvin or anyone else—and instead most commonly referred to themselves as members of the "Church reformed according to the Word of God" or simply as "those of the cause."

If Calvinism cannot be traced exclusively to one person, it also cannot be reduced to the presence of two or three fixed teachings. If one is to judge from the Westminster Confession and Catechisms (1646–1647), the Heidelberg Catechism (1563), and the Second Helvetic Confession (1566), the most prominent components of Calvinism include the centrality of the person and work of the Mediator; the work of the Holy Spirit in the right interpretation of the normative Scriptures of the Old and New Testaments; the emphasis on the Church as the body of the elect and their assurance of salvation; justification and sanctification by grace alone through faith and the positive use of the law in guiding believers; the importance of the ordinary means of grace; and the need to translate the sovereignty of God into transforming political, educational, and economic structures. In polemical debate Calvinists were often divided over the implications of any given doctrine of predestination, especially concerning the question of free will and whether atonement is universal or limited.

See also CHRISTIANITY, REFORMED, ISSUES IN SCIENCE AND RELIGION

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CARTESIANISM

Cartesianism is the name given to the philosophical movement initiated by French mathematician and philosopher René Descartes (1596–1650) on the basis of two key innovations. The first is Descartes's claim that material events, including most biological phenomena, can and must be explained without appeal to teleological principles or occult qualities, through laws of motion acting mechanically on microcorpuscular bodies having no properties beyond spatial extension and shape. Descartes's second claim, his *dualism,* is that the distinctive human properties of selective intentionality and free volition, dramatically manifest in the creative freedom of language, mark human beings off from other animals as innately possessed of an immaterial soul or mind that is ontologically independent of matter, characterized by infinite moral freedom, susceptible of a distinct happiness, and capable of continued existence after the body's demise.

In Descartes's day, the first claim was by far the most controversial: how can living, breathing beings, plants and bees and horses, emerge from purely mechanical laws acting invariably on inert matter? As a program for physics, Descartes's elegant reductionism was fatally undermined when Isaac Newton in 1687 successfully accounted for universal gravitation by adding without metaphysical justification the notion of force. However, Cartesian mechanistic parameters continued fruitfully to guide biology and experimental physiology, shaping the speculative outlook of such diverse scientists as Julien de la Mettrie (1709–1751) and Claude Bernard (1813–1878). Today, Cartesianism survives in the methodological premise, also adopted by Newtonians, that a large part of sensible phenomena derives from causes acting invariably, without intention or free volition.

See also DESCARTES, RENÉ; DUALISM; MATERIALISM; NATURALISM; PHYSICALISM, REDUCTIVE AND NONREDUCTIVE; REDUCTIONISM

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CATASTROPHISM

Catastrophism is a doctrine originally proposed by French zoologist Georges Cuvier (1769–1832) in 1810 to explain large geological and biological changes in the earth's history. The discovery of extinct animal and plant species under a coarse superficial deposit (diluvium) lead English geologist William Buckland (1784–1856) and others to suggest that this was caused by the biblical flood, which was then followed by the divine recreation of the animal and plant species living today (creationism). Scottish geologist Charles Lyell (1797–1875) rejected catastrophism and suggested that the same geological forces apparent today had always been at work on the earth, gradually changing the earth's surface and its biological species (gradualism). Today diluvium is attributed to glacial drift.

See also CREATIONISM; GRADUALISM

ARN O. GYLDENHOLM

CATHOLICISM

See CHRISTIANITY, ROMAN CATHOLIC, ISSUES IN SCIENCE AND RELIGION

CAUSALITY, PRIMARY AND SECONDARY

In the history of Christian thought, the philosopher Thomas Aquinas (c. 1225–1274) refers to God as the "Primary Cause" of the being of everything; Aquinas refers to creatures as "secondary causes" whose activity reaches particular aspects and depends on divine action. These concepts are related to core Christian ideas of God and creatures. God's being does not depend on anything outside God, is self-sufficient, and is the fountain of the being of all that exists. Creatures have their own consistency but require the divine founding action that makes possible their existence and activity.

The Primary Cause is unique. It is not the first of a series of causes belonging to the same level. God's action is different from created action. God does not substitute creatures (except in miracles). God not only respects the activity of the creatures, God is its main guarantee, as created agency corresponds to God's plans.

These ideas have often been appropriated by religion to speak of God's complementary action in the world of creatures. God creates in order to communicate being and perfection, and creatures fulfill God's plans when they deploy their capacities and reach their perfection.

Empirical science studies the nature and activity of secondary causes. Metaphysics and theology study divine action and the spiritual dimensions of the human being. These two perspectives should be different and complementary, but are not necessary opposed.

Difficulties in harmonizing evolution and God's action often resulted from disregarding the distinction between first order and second order causality. Cosmic and biological evolution can be considered as the deployment of the potentialities that God has placed within created beings. Natural finality and God's plans also correspond to two related but different levels.

The modern scientific worldview shows that natural beings possess an inner dynamism that produces new results that have ever increasing degrees of complexity. In natural processes the concept of information plays a central role. Natural information exists coded in dynamic structures, and its deployment produces new structures. Natural activity shows a high degree of creativity which, in conjunction with the subtlety of natural processes and their results, could be seen as coherent with the existence of a divine plan. The new paradigm of self-organization was metaphorically anticipated by Aquinas who wrote in his *Commentary on Aristotle's Physics*: "Nature is nothing but the plan of some art, namely a divine one, put into things themselves, by which those things move towards a concrete end: as if the man who builds up a ship could give to the pieces of wood that they could move by themselves to produce the form of the ship" (p. 124).

This worldview does not lead to metaphysical or theological consequences by itself. Reflection upon it, however, paves the way for an understanding of natural agency as supported by a founding divine action that does not oppose nature but rather provides it with its ultimate grounding. The world can be represented as an unfinished symphony where human beings have a role to play.

See also CAUSATION; DIVINE ACTION; THOMAS AQUINAS

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MARIANO ARTIGAS

CAUSATION

The notion of cause is one of the most common yet thorniest concepts in the history of philosophy. This should come as no surprise. Questions of causation tie up with such divisive issues as determinism and moral responsibility, as well as with the principle of the causal closure of the physical universe and the possibility of divine action. Furthermore, causation is intimately intertwined with the notion of change. Together these two notions stood at the cradle of such momentous intellectual traditions as Western philosophy in Asia Minor, the Vedic hymns and the Upanishads in Central and South Asia, and early Buddhism along the borders of the ancient Ganges. They constituted the first and fundamental challenge to systematic thought, inspiring a variety of solutions still resonating in intellectual debates.

People use causal idiom in everyday life with great ease, yet upon closer scrutiny this family of notions seems to defy analysis and justification. The famous comment of Augustine of Hippo (354–430) regarding the question of time applies with equal force to the analogous question concerning causation: When nobody asks us, we know what it means; when queried, we don't.

Quite generally, a *cause* produces something called the *effect*; and the effect can be explained in terms of the cause. Usually the effect is taken to be a change in something already existing. Yet in traditional theology it has also been assumed that causes may give rise to new substances out of nothing. Thus in the Judeo-Christian tradition God is seen as the creator of the universe, which God created out of nothing. Similarly, theories of self-causation and creation by God were two of the major causal theories in the Vedic tradition. By contrast, early Buddhism rejected these two views, arguing that the idea of self-causation would imply the prior existence of the effect, while the idea of external causation would imply the production of a nonexistent effect out of nothing. Similarly, Thomas Aquinas (c. 1225–1274) rejected the theological notion of self-causation as philosophically untenable. God cannot possibly be regarded as *causa sui,* he argued, since either God existed to cause God, in which case God did not need to cause God; or else God did not yet exist, in which case God could not be anything to be able to cause God.

Aristotle's theory of causation

Aristotle (384–322 B.C.E.), too, regarded causes as producing changes in preexisting substances only. To be sure, when a moth emerges from a caterpillar the change is so striking that a new word is naturally used for the causal product. And yet the moth emerged from the pre-existing caterpillar. By contrast, when a leaf turns red, it is still called a leaf, because the change is less striking. Aristotle called the former type of change *generation,* as opposed to the merely qualitative change—or, in his terminology, motion (*kinesis*)—taking place in the latter kind of case. Yet the distinction is plainly a relative one, opposing rather than licensing the idea of new substances being producible out of nothing by a cause. Indeed, the conception of creation *ex nihilo* is foreign to the whole tradition of ancient Greek thought.

Commenting on Plato (428–347 B.C.E.) as well as on his pre-Socratic predecessors, Aristotle famously distinguished four types of causes or explanatory principles (the Greek word *aitia* is ambiguous between these two rather different meanings). A statue of Zeus, for example, is wrought by a sculptor (its efficient cause or *causa efficiens,* also known as the *causa quod*) out of marble (the material cause or *causa materialis*), which thereby takes on the shape the artist has in mind (the formal cause or *causa formalis*) in order that it may serve as an object of worship (the final cause or *causa finalis,* also known as the *causa ut*). Plato's forms, or formal causes (*causa exemplaris*), had been transcendent ideas in the mind of the Demiurge. By contrast, in Aristotle's theory of natural change the four causes together have an immanent teleological character. The form being developed is an integral part of the thing itself. Thus, the formal cause for an acorn developing into an oak tree is the seed's intrinsic character disposing it to become an oak tree rather than, say, a maple tree.

Naturally Aristotle's largely teleological theory of causation authorized the abundant use of final causes in explanations of natural phenomena. Thus his theory of motion espoused the principle that objects strive toward their *locus naturalis,* while medieval hydraulics—just to give another example—promulgated the principle that nature abhors a vacuum (*Natura abhorret vacuum*).

Mechanicism and the demise of the teleological theory of causation

While medieval scholastic thought was still dominated by Aristotle's theory of causation, seventeenth-century science opposed its teleological underpinnings. Natural order and change, it claimed, could be produced by "blind" efficient causation alone, without the need of final or formal causes intervening in the process. Having created the matter of the universe together with the laws of mechanics, God could have left the world to its own in any disordered fashion, claims René Descartes (1596–1650) in *Le Monde,* and yet in due course the universe would have taken on its current natural order of celestial motions and "terrestrial" physics mechanically, driven blindly by efficient causes alone and without "striving" to achieve any final perfections or divine purposes.

This conception of the causal "machinery" of the universe being limited to efficient causation presented a stimulating and exceedingly fruitful research program to modern science. In due course its validity was proclaimed to extend not just to mechanics proper, but also to physiology and chemistry, to biology (in the Darwinian program), to ethology, and even to the realm of human action in twentieth-century sociobiology and of human thought in late-twentieth-century cognitive science. And yet, from the very start, the program spawned riddles and grave philosophical difficulties. Chief among these was the difficulty involved in the widely held view that linked (efficient) causation to necessity. David Hume (1711–1776) notoriously pointed out that causal pairs are related neither by logical nor by empirical necessity. It is both logically and empirically possible for an effect to fail to follow a given cause. In fact Hume's influential argument had a theological background.

French theological tradition, including notably Descartes and Nicolas Malebranche (1638–1715), had always been keen to stress the point that God's freedom is unfettered by any restrictions whatsoever. Hence given any cause, God is always free not to permit the effect to follow. Thus, causes alone, unaccompanied by the will of God, are never sufficient conditions for their effects. Nor, given God's omnipotence, can they be allowed to be necessary conditions for their effects. For God is free to bring about the effect by any other mediating cause or even by simply willing it.

Having failed to find an empirical basis for the idea of necessary connection in the case of *singular* causation, Hume turned his attention (without making a clear distinction) to the case of causation as it exists between *classes* of (similar) events. Analyzing this latter notion Hume advanced a regularity theory of causation. Eschewing powers and necessary connections, Hume thought causation could be adequately dealt with in terms of the "constant conjunction" of similar causes with similar effects. In addition, conditions of temporal priority and spatiotemporal contiguity were also required. This analysis, in Hume's view, had the distinct merit of being entirely empirical. Yet subsequent generations of (logical) empiricists have found, to their exasperation, that the empiricist ideals are not that easily fulfilled.

One difficulty is that of distinguishing between accidental and genuinely causal regularities. As the Scottish philosopher Thomas Reid (1710–1796) famously remarked in his *Essays on the Active Powers of the Human Mind* (1788), day is invariably followed by night and night by day and yet neither is the cause of the other. One tempting way to find a distinctive mark is to say that statements of causal regularities, unlike those that express merely accidental generalizations, are supported by corresponding counterfactuals. Thus, it is presumably true that a given piece of metal would have expanded had it been heated. By contrast, even if all the marbles in a given bag happen to be red, that fact alone doesn't add credence to the counterfactual that had the green marble in my hand been a marble in that bag, it would have been red. Yet, reliance on counterfactuals would involve a high price for empiricists to pay. For the truth conditions of counterfactuals are notoriously beyond the reach of empirical verification.

Another difficulty was raised by Bertrand Russell (1872–1970), who noted that in order for events to be causally connected they must be similar not just in arbitrary respects, but in *relevant* respects. For example, two matches may differ only in color or, alternatively, only in one being wet while the other is dry. Yet for the question of whether striking them will cause them to ignite only the latter dissimilarity counts while the former is entirely irrelevant. But how is one going to specify this notion of relevance? One is tempted to rely on an undefined notion of *causal* relevance. But that would critically trivialize Hume's analysis because it would utilize the notion of causation in the very attempt to analyze it.

Oriental theories of causation

For Hume, then, the idea of causation, insofar as it is mistakenly bound up with such unfounded notions as power or necessary connection, does not represent anything objective. The implied idea of necessity does not arise from anything in the external world. Rather it results from a mental response to the constant conjunction of causes and their effects. By comparison, in Indian philosophy the objectivity of causation has been subject to considerable shifts of opinion. The first to deny the principle of causation was the idealist school of the Upanishads. Insisting that reality and soul (*atman*) were permanent and eternal, they denied change and therefore causation. Like Hume, but for different "Parmenidean" reasons, these thinkers considered change and causation mental constructs, or purely subjective phenomena. Conversely, the consequent denial of *atman* or self among early Buddhist materialists led to fruitful speculation regarding causality and change. However, in their extreme aversion to the idealist metaphysics of the Upanishads, these materialists went on to deny all mental phenomena. This annihilationism is opposed to the earlier belief of Upanishad philosophers in eternalism. However, according to the "middle path" preached by the Buddha, both positions are errors stemming from two opposite extremes with regard to causation, which early Buddhism set out to steer clear of: on the one hand the belief in self-causation, resulting in a belief in eternalism; on the other the belief in external causation, fostering a belief in annihilationism. While early Buddhism, like Hume, rejected the belief in a mental substance or "self," it did not share his conclusion that "were all my perceptions remov'd by death […] I shou'd be entirely annihilated … " (Hume, p. 252). The reason for this is precisely that unlike Hume early Buddhism insisted on the objective validity of causal processes, which it referred to as constituting the "middle" between the two extremes of eternalism and annihilationism. Consequently it regarded such causal processes sufficient for sustaining the continuity of a thing without positing a "self" or a "substance."

The importance of causality as an objective category in early Buddhism is brought out clearly by the fact that of the four noble truths discovered by the Buddha, the second and the third refer to the theory of causation. In the early Pali Nikayas and Chinese Agamas causation is not a category of relations among ideas but represents an objective ontological feature of the external world. Yet there has been much debate concerning the notion of *avitathata,* the second characteristic of the causal nexus in Buddhist philosophy. The Buddhist philosopher Buddhaghosa (late fourth and early fifth centuries C.E.) rendered this concept as "necessity," while others have championed a rather deflationary Humean interpretation of mere regularity and constant conjunction. From a more balanced perspective, what seems to be at stake in such discussions is to free causation from strict determinism. Thus a fourth characteristic of causation, *idappaccayata* or conditionality, is supposed to place causality midway between fatalism (*niyativada*), or unconditional necessity, and accidentalism (*yadrc-chavada*), or unconditional arbitrariness. Clearly, the underlying concern here is the problem of moral responsibility, which Buddhist thinkers are anxious to uphold.

Volitional causation

Taking their clue from Hume that causality is not a physical connection inasmuch as one never observes any hidden power in any given cause, philosophers of an empiricist bent have insisted ever since on analyses of causality in terms of necessary and sufficient conditions for the applicability of the term. Thus, they focused on the logical and linguistic aspects of the notion of causality to the neglect of trying to find a physical connection between cause and effect. An example is John L. Mackie's (1917–) sophisticated regularity account in *The Cement of the Universe* (1974).Yet the contrary opinion has not been without its adherents. Even before Hume, John Locke (1632–1704), while discussing causality, appealed to the model of human volition. When one raises one's arm, he argued, one is directly aware of the power of one's volition to bring about the action.

This *purposive* perspective on causation has independent merits. For one thing it can make perfectly good sense of singular causation. For another, it avoids the vexing problem of so-called causal asymmetry. The fact that one ordinarily refuses to allow effects to precede their causes—Hume's condition of the temporal priority of causes—may on this view simply be seen as a natural consequence of the familiar experience that whatever actions one initiates cannot bring about the past. In fact, this volitional model of causation has been more influential than is generally acknowledged even among protagonists of the scientific revolution. Thus Isaac Newton (1642–1727) toyed with, and George Berkeley (1685–1753) championed, a theological construal of gravitation. Instead of invoking gravitational action-at-a-distance, a notion that Newton himself had deemed embarrassing enough to keep his theory locked up in a drawer for almost twenty years, it was, according to this view, God's own intervention that caused the sun ever so slightly to drift toward such large but immensely distant planets such as Jupiter, in accordance with mathematical patterns and laws that Newton had the genius to unravel. Needless to say, such animistic astronomy fails to carry conviction at the present time. But it is good to realize, if only for expository purposes, that Berkeley's animistic world is not a world without causation. Rather it is a world where all causation is volitional. When this world is stripped of volitional causation, what remains is a "Hume world," a world truly without causation. If philosophers have found such a world equally unconvincing, they could then ask the critical question: What crucial ingredient is the Hume world lacking that our world supposedly possesses?

Recent debates: realist vs. pragmatist views on causation

Apparently there are at least two ways to go from there: One can follow either the realist or the Kantian-pragmatist way out. The opposition in question is neatly exemplified by two contemporary schools of thought on causation, one represented by Wesley Salmon (1925–2001), the other highlighted by the philosophy of Philip Kitcher (1947–). Salmon has argued that there does exist, after all, an empirically verifiable physical connection between cause and effect. It is to be found in the notion of a causal process, rather than in that of a causal interaction, which Hume mistakenly took as his paradigm. Furthermore, thanks to the theory of relativity that sets an upper limit to the transmission of causal signals, we can now empirically distinguish between genuinely causal processes (e.g., light rays traveling at straight lines from a rotating beacon to the surrounding wall of, say, the Colosseum) and mere pseudoprocesses (e.g., a spot of light "traveling" along the inner wall of the Colosseum as a result of a central beacon rotating at very high speed). While pseudoprocesses may travel at arbitrarily high velocities, they cannot transmit information as only causal processes can. Similarly, the actions of a cowboy on a cinema screen are pseudoprocesses. When, in excessive excitement, you shoot him, it has no lasting effect on the cowboy, but only on the screen. Thus, in Salmon's view, the capacity to transmit information (or rather, conserved energy) constitutes empirical proof that the relevant process is genuinely causal in nature rather than a mere pseudoprocess.

According to this realist view, therefore, causation is a robust physical ingredient within our world itself, *entailing* necessary and sufficient conditions (or causal laws, probabilistic or otherwise), rather than *being entailed* by these. Causation is essentially a "local" affair, depending on the intrinsic features of two causally related events. By contrast, causal laws and necessary and sufficient conditions are "global" features, depending on the world as a whole. Consequently, on this realist view, causality may be entirely compatible with indeterminism, while theories couched in terms of necessary and sufficient conditions run into grave difficulties when confronted with the pervasiveness of indeterminacy in the subatomic realm.

Yet Salmon's theory has not been without its detractors. Thus, having confronted the theory with ingenious counter examples, Kitcher has argued that Salmon's theory, just like the empiricist theories before him, ultimately comes to rest on the truth of empirically unverifiable counterfactuals. By contrast, Kitcher's own theory places causality squarely within a Kantian-Peircian perspective. Immanuel Kant (1724–1804), while conceding to Hume that causality may be unobservable in the physical world, contradicted Hume's conclusion that therefore causality is not a real feature of the world *as we know it.* Indeed, causality may not be a feature positively discoverable in what Kant called the *noumenal* world, that is, the world as it exists in itself, without regard to the structural limitations of human knowledge. But then again, nothing is so discoverable or attributable. And yet causality is a property objectively ascribable to the *phenomenal* world, that is, the world as structured by the conceptual and perceptual features inherent in human cognitive capacities. As a result of the necessarily synthetic activities of human reason, one cannot *conceive* of the empirical world except in terms of causes and effects. The causal relation is therefore as firmly and objectively established as are space and time, which constitute the a priori forms of *perception* of the empirical world. These are all verifiable attributes of the physical world, which is part of the phenomenal world, the only kind of world humans are capable of knowing in principle.

Thus, the fundamental notion of causation receives a distinctly epistemological underpinning in Kantian philosophy. This is what ties Kitcher's philosophy of causation in part to the Kantian tradition. Thus, Kitcher has stated that the *because* of causation derives from the *because* of explanation. Rather than being an independent metaphysical notion, what may and may not be recognized as truly causal relations depends in the final analysis on epistemological constraints. In Kitcher's view the ultimate aim of science is to generate theories of the universe as unified and simple (or all-encompassing) as possible. Which theories are finally recognized—in the ideal end of inquiry, to borrow the famous words of the pragmatist Charles Sanders Peirce (1839–1914)—as optimally unified and robust thus determine what causes are recognized as genuinely operative and effective in the only world humans can possibly come to understand. Thus, in Kitcher's view, the metaphysical significance of causation ultimately derives from its key role in the best possible theory of the universe we will be able to generate. In a sense, therefore, causation, rather than being a metaphysically realist notion, is better seen as an unadulterated epistemological notion, dependent not on what we stumble upon in observation of singular cases of causation, as realists like Salmon would have it, but rather on the excellency of the theories that best account for the physical features of the world as a whole.

See also DOWNWARD CAUSATION; UPWARD CAUSATION

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THEO C. MEYERING

CHANCE

In both science and religion there is a lively debate about the role of chance in the universe. In science, this debate usual takes the form of a discussion deciding between determinism (all events follow of necessity from prior initial conditions) and physical indeterminism (some events, at least, are not so determined). In religion, the dispute is between those who accept total predestination (the view that God unilaterally ordains everything that happens) and theological indeterminism (God leaves some things to chance or to determination by finite agents). Most religious views deny any role for pure chance, but many allow some role for chance even in a providentially-governed universe. Debate is often clouded by a failure to define what "chance" is.

Different senses of chance

In its most radical sense, chance is the occurrence of an event without any cause or reason. Thus the universe may be said to come into existence for no reason and without any antecedent cause—by chance. In this sense, absolutely anything might happen at any time, and there is no point in seeking reasons for what happens. If everything happened by chance, in this sense, science would be impossible.

Another, more common, sense of chance is involved in gambling or lotteries. When a gambler throws a die, the side that lands uppermost is a matter of chance. It is not that there are no causes for the position of the die, but that the causes are far too difficult, complex, or tedious to be detected. The roll of the die could be determined in every particular by applying the laws of mechanics, but it would still be considered a matter of chance because the system is set up so that no human can predict the outcome. In this case, chance primarily refers to unpredictability; whether something is chance or not depends on the knowledge available to the observer.

Another sense is that in which something happens "by chance" because it is not intended by any agent. A person may meet a long-lost friend by chance if neither the person nor the friend nor God had intended the meeting to happen, or tried to bring it about. Genetic mutations are said to be random, to occur by chance, in this sense. They have causes, but they are not intended to happen as they do.

This sense can be extended to events that are not parts of any directional process or propensity. Thus, many geneticists would say that genetic mutations do not tend in any particular direction (they do not, for example, always occur so as to maximize the chances of survival for some organism). This view is contentious, for some argue that there are propensities in organic mutation; the process does tend to realize consciousness eventually, and this tendency is inbuilt in the system from the beginning. If this were true, particular mutations could happen by chance (they would not each be determined to increase the chances of consciousness coming into being), but the process as a whole (the whole set of mutations in their environmental context) might have a propensity to terminate in consciousness.

This introduces yet another sense of chance, for which particular events have a specific probability of occurring, but are not sufficiently determined. An event is sufficiently determined when, given its initial conditions and the laws of nature, it could not happen in any other way. An event is not sufficiently determined when, from the very same initial conditions and laws, there are a number of possible effects that could result. In other words, the same cause in the same situation can have different effects. Some physicists have denied this possibility, but the Copenhagen Interpretation of quantum mechanics asserts precisely that particular subatomic events have a highly specific probability of occurring in a specific way, but they may not do so. When large numbers of quantum events occur, however, this probability will turn into a predictable certainty—thus the equations of quantum mechanics are deterministic, though they refer to events that are to some extent indeterminate. Such processes are called "stochastic"; there is a high probability that specific types of events will occur, but particular events may be unpredictable and not sufficiently determined.

Implications for freedom

There are thus two main components of the idea of chance—lack of predictability and lack of sufficient causality. For some philosophers, human freedom requires chance, since humans could not be held responsible for their actions if they were sufficiently caused (if they were determined by some cause, whether natural or divine) to act as they do. According to this view, chance is a necessary condition of responsible freedom. A free act is distinguished from a purely arbitrary (non-caused) act by being intentional, initiated for a purpose.

A believer in God may say that the creation of the universe is the primary instance of a free act. Creation is not caused by any prior initial state or by some general laws, but it is brought about for a reason. God has some value or values in mind, and realizes them by creating the universe. A free act is thus a form of causality for the sake of realizing some envisaged value. This causality distinguishes such an act sharply from pure chance, even though the act may appear unpredictable and undetermined from the point of view of physical laws and prior physical or mental states.

Some theologians have proposed that quantum mechanics shows the fundamental laws of the universe to be stochastic, or statistical, rather than deterministic. This, they claim, would permit both human free acts to occur, and would also allow God to act freely within the statistical probabilities of the physical system without "breaking" any laws of nature. For others, it is much too restrictive to confine God's free actions to scrabbling around in the sub-atomic basement. In any case, quantum indeterminacies cancel out because of the large numbers of probabilistic events involved in supra-atomic events, which means that the overall statistical distribution is virtually uncertain.

The existence of dynamic systems far from equilibrium allows quantum fluctuations to be amplified to produce macrocosmic effects. Thus in the right circumstances (in the brain, for example) quantum indeterminacies could produce huge observable indeterminacies in nature. Or it could be held that, quantum considerations apart, laws of nature are in themselves probabilistic, operating on an "other things being equal" basis, and they do not exclude free, or teleological causality, at all.

Religious views cannot easily live with any supposition of pure chance, in the radical sense. Most classical theistic views are deterministic (all is determined by God), seeing freedom as compatible with determinism. But in the twentieth century there has been an increase in the number of people holding nondeterministic views, for which chance (as probabilistic indeterminism) allows free creative activity both of creatures and of God, and a mutual responsiveness of creaturely and divine acts that may be held to be close to a biblical perspective.

See also COMPLEXITY; CONTINGENCY; CONVERGENCE

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CHAOS, QUANTUM

Quantum Chaos connects quantum and chaos physics, giving rise to two fundamentally different versions of indeterminism. Quantum mechanics holds that classical particle trajectories become indeterminate when studied under conditions that bring forth the wave nature of matter. Within classical physics, trajectories follow deterministic laws but are nevertheless unpredictable if the motion is chaotic. Quantum indeterminism and classical chaos conspire to create effects that become observable at the transition between microscopic (atomic) and macroscopic scales. For example, a characteristic phenomenon of quantum chaos is that quantum wave effects help suppress the instability of chaotic motion.

See also CHAOS THEORY; PHYSICS, QUANTUM; UNPREDICTABILITY

WOLFGANG ACHTNER
JENS NOECKEL

CHAOS, RELIGIOUS AND PHILOSOPHICAL ASPECTS

The word *chaos* appears in a variety of scholarly disciplines. This entry will address its use in the Greek philosophical tradition and a number of religious traditions. Chaos will also be explored in its use in scientific cosmology.

Religious and philosophical traditions

It is characteristic of ancient Greek thought to see the world (*cosmos*) as coming into existence through the imposition of order on preexisting *chaos.* The first known usage of the term *chaos* is in the *Theogony* of Hesiod (late eight century B.C.E.); Hesiod probably took up the idea from earlier mythological accounts of the beginning of the universe. For Hesiod, chaos refers to the preexisting undifferentiated state of things. It manifests itself in the gap between heaven and Earth that occurs as the world emerges. This chaotic gap is transformed by the appearance of Eros, a fertilizing force that brings heaven and Earth back into a creative embrace. The word cosmos was used by philosophers from Pythagoras (569–475 B.C.E.) to Archimedes (287–212 B.C.E.) to describe the order that is manifest in the natural world. Both Plato (in *Timaeus*) and Aristotle (in *Physics*) interpreted chaos in terms of the pre-philosophical concept of space. Zeno of Citium (333–264 B.C.E.) associated chaos with water. The Stoics understood chaos as referring to the watery state that occurs periodically when the universe is destroyed by fire.

There are a number of different symbols for chaos among the peoples of the Earth. Two are widespread: the waters of the deep and the cosmic egg or embryo-like form that is the matrix for all things. But chaos is also envisioned as a dragon, as a hybrid human-animal, as a dangerous female mother associated with the waters or the Earth, and as a cosmic giant figure. It appears in popular culture in the figures of the demon, the witch, the trickster, and sometimes the shaman.

Religious traditions from different parts of the world express the defeat of chaos in their myths and rituals of combat. This pattern found expression in the ancient Near East. The Babylonian epic poem *Enuma Elish,* which dates in part back to the second millenium B.C.E., is good example. It tells of a great battle in which a sky god, Marduk, wins a victory over Tiamat, a female chaos figure associated with the primeval waters. Marduk slays Tiamat and divides her body to form the world, using her skin to keep out and confine the waters in the heavens and in the underground. The story establishes the legitimacy of the temple and rule of Babylon. Tiamat has been interpreted as referring to an older impotent order of society and divine beings that is replaced by the new.

In the Canaanite myths of Ugarit, Baal engages in warfare with the adversary Mot, with another adversary called the Sea, and with Leviathan or Shalyat of the seven heads. This kind of combat also appears in the Hebrew Bible, in Isaiah 27:1, where Leviathan is mentioned; in Psalm 74:13–15; 89:10–11; in Isaiah 51:9; and in Job 9:13; 26:12; 38:8–11. In these texts the monster is often constrained rather than destroyed. God is understood as continually creating and defending the universe against disintegration and chaos.

The Bible begins with an account of creation that seems to go back to priestly sources of the sixth century B.C.E. According to the Bible the "the earth was a formless void and darkness covered the face of the deep, while a wind from God swept over the face of the waters" (Gen. 1:2). "Formless void" translates the Hebrew words *tohu wabohu*. The word *tohu* appears in the Bible twenty times, with the meaning of formless, shapeless, and uninhabitable. The word *wabohu* appears three times, with a similar meaning. Two chaotic elements characterize the formless void, the primordial waters and darkness. God vanquishes darkness on the first day of creation with the creation of light. Darkness is not completely destroyed, but is limited to the night, as part of good creation (Gen. 1:5). The chaotic waters that cover the whole Earth (Pss. 104:6) are brought under divine control on the second and third days. God positions a gigantic concave plate or dome to separate the waters above from the Earth below (Gen. 1:7) and then sets boundaries to the seas so that dry land can appear (Gen. 1:9). The explicit idea of creation *ex nihilo* does not appear in Jewish thought until the second century B.C.E. (2 Macc. 7:28).

In the stories and rituals of the indigenous peoples of Australia, Africa, and North and South America, there are times when participants experience a liminal state that can be understood as a return to the creative boundaries between chaos and order. Alongside the religious traditions that emphasize the defeat of chaos, there are those that challenge dualistic polarities and encourage an acceptance of chaos or elements associated with it, such as negativity, unknowing, and darkness. In ancient China, early Daoist texts (as opposed to the later Daoism) support mystical union with *hun-tun* (chaos) and identify hun-tun with the ultimate principle of Dao. Alongside the mainstream Vedic traditions of India there are forms of mysticism, both Upanishadic and Buddhist, that encourage union with "emptiness." Christian theology includes the tradition of apophatic theology, which finds expression in the works of Gregory of Nyssa (c. 335–c.395 C.E.) and Pseudo-Dionysius (c. fifth century C.E.), in the English medieval text *The Cloud of Unknowing,* in the John of the Cross's (1542–1591) symbol of the Dark Night, and in the twentieth century in Karl Rahner's (1904–1984) theology of God as Incomprehensible Mystery.

In Jewish thought, a theology that can embrace negativity finds expression in various streams of thought, including those concerning God's *Shekinah* and sixteenth-century mystic Isaac Luria's concept of the divine withdrawal that makes space for creation (the *zimsum*). In philosophy since the Holocaust, there has been an attempt to embrace the chaotic strangeness and alterity of reality, particularly in the postmodern rejection of all "totalizing" attempts at comprehension and order and in philosopher Emmanuel Levinas's (1906–1995) insistence on the radical and irreducible otherness of one's neighbor.

Scientific cosmology

In the scientific cosmology that emerged during the twentieth century, ancient ideas of the emergence of cosmos from chaos were replaced by the idea of a universe that has expanded and evolved over the course of twelve billion to fifteen billion years from a tiny, dense, and hot state. The Big Bang theory of cosmology had its origins in models of the universe based on Albert Einstein's theory of General Relativity. According to these theories, space-time itself emerges and stretches in the process of cosmic expansion. Over the last century a number of lines of evidence have supported Big Bang cosmology, particularly the discoveries of the red shifting of galaxies, the abundance of helium and deuterium in the universe, and background microwave radiation. According to standard Big Bang cosmology the universe is expanding and also decreasing in temperature and density, and this points back to a beginning of the universe of unthinkable smallness, density, and heat—to an original singularity. A singularity is a point at which the density and the curvature of space-time are infinite, a point at which the laws of physics no longer hold.

In 1948, physicists Fred Hoyle, Thomas Gold, and Hermann Bondi put forward an alternative to Big Bang cosmology with their *steady-state* idea of the universe. In this theory new matter and new galaxies are continuously brought into being, in a stable universe that has an infinite past. Although the steady-state theory was undermined by the discovery of background microwave radiation, some of its philosophical aims were incorporated into a

Big Bang framework in what physicist Charles Misner called *chaotic cosmology.* Chaotic cosmology seeks to avoid attributing the order of the universe to initial conditions. It is committed to explaining the present nature of the universe without requiring knowledge of its initial state. It seeks to show that no matter how chaotic the state of the universe at the beginning of its expansion, there are processes that can smooth out irregularities and produce the isotropic and uniform universe that people can observe. But no known process could account for this smoothing out process until the rise of inflationary theories in the 1980s.

In the meantime cosmologists had begun to speculate about the beginning of the universe in terms of quantum theory. Quantum field theories differ from their classical predecessors in the way they understand a vacuum. Within quantum theory, a vacuum is not understood simply as nothing at all, but as a sea of continuously appearing and disappearing pairs of oppositely charged particles. These processes are unobservable at the individual level and are called *virtual,* but are measurable at the collective level. The quantum vacuum is an infinite sea of virtual processes. Quantum theory allows for the spontaneous appearance of energy in the quantum vacuum for a very short time, as long as it is unobservable. Quantum cosmology involves a theory of the emergence of the universe from a fluctuation of the quantum vacuum. It thus, once again, suggests that an ordered universe appears from a chaotic initial state.

Chaos was to reenter the language of cosmology in the form of the theory of *chaotic inflation.* In order to solve some of the problems associated with the Big Bang, physicist Alan Guth in 1980 proposed that within a fraction of the first second the universe went through a period of extremely rapid expansion or inflation. Soon after, in 1983, physicist Andrei Linde put forward his theory of chaotic inflation, which dispenses with the idea of most initial conditions including the initial heat. The universe begins from chaos in the form of the seething ocean of different forms of scalar fields. The observable universe began from one such field, as one part of a process that may involve an unlimited ensemble of universes. In many recent models of the expanding universe, particularly those based on a period of rapid inflation, the observable universe would be a small domain within a much bigger universe, perhaps an infinite and eternal one.

In all of these theories, inflation provides the ordering principle, and chaos reappears in the initial conditions of the universe. As astronomer John Barrow has said: “Inflation does not explain the uniformity of the Visible Universe by eradicating primordial chaos, but by sweeping its effects out of sight beyond the boundary of the visible part of the Universe” (p. 239). It is worth keeping in mind that at this stage there is much more evidence for Big Bang cosmology in general than there is for the various forms of chaotic cosmology. In a recent evaluation of the major theories of cosmology, physicist P. James E. Peebles concludes that while there is compelling evidence that the universe has evolved from a hotter and denser state, the theory of inflation is “elegant, but lacks direct evidence and requires huge extrapolation of the laws of physics” (p. 45).

Conclusion

For many communities, chaos represents the strangeness and otherness of reality. As such it may be unwise to understand chaos and cosmos as simply opposed to one another. It is not simply that an ordered cosmos emerges from and replaces chaos. In many cultural systems chaos may be defeated but nevertheless reappears. It can be seen as an ever-returning dimension of human existence in the world. Even in the midst of ordered lives, human beings continually experience the chaotic, in the wildness of the wind in a storm, in the untamable violence of the sea, and in the dark and lonely hours of the night. It can be a threat and a challenge. But it can also have the character of the mysterious and uncontrollable ground or source from which all things spring. It can represent the possibility of creativity and of the new.

See also BIG BANG THEORY; CHAOS THEORY; CREATIO EX NIHILO; DISORDER; INFLATIONARY UNIVERSE THEORY

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DENIS EDWARDS

CHAOS THEORY

Chaos Theory (CT) is a mathematical theory about nonlinear dynamical systems that exhibit exquisite sensitivity to initial conditions, eventual unpredictability, and other intriguing features despite the inevitably deterministic character of mathematical equations. CT has been used to model processes in diverse fields, including physics (quantum chaos, nonequilibrium thermodynamics), chemistry, ecology, economics, physiology, meteorology, zoology, and the neurosciences.

Basic research in mathematics and physics during the twentieth century produced CT. Felix Hausdorff (1869–1942) made essential contributions in mathematics when he created spaces with fractional dimensions. When Benoit Mandelbrot (1924–) applied these spaces to geometry, he discovered new objects that he called *fractals.* These ideas were combined with the study of recursive and iterative mathematical formulas. The simplest formula of this kind, which was explored in great detail by Mitchell Feigenbaum (1944–), is the logistic equation $x_{n+1} = ax_n (1 - x_n)$, where a is a *tuning* constant for the system. The system evolves recursively for $n = 0, 1, 2, 3, \ldots$.

In 1963, meteorologist Edward Lorenz (1917–) used differential equations with chaotic properties to model a physical system, the first time this had been done. In physics Henri Poincaré (1854–1912) used features of CT to demonstrate the stability of the solar system, a result that Isaac Newton (1642–1727) and many other scientists had not been able to achieve because of the potentially chaotic behavior of systems containing three or more bodies. Ilya Prigogine (1917–), who did research in thermodynamics, examined nonlinear systems that are far from equilibrium and showed that such a system could generate novel structural features.

All these developments were independent of each other, but they merged in the new concept of CT in the 1970s. The term *chaos theory* was coined by mathematician and physicist James Yorke around 1972 and was introduced to the scientific literature in 1975 by the mathematician and biologist Robert May. Robert Devaney gave the first mathematical-technical definition of chaos in 1989, although this definition does not cover all features of interest to mathematicians who study chaos. In this technical sense, CT is not to be understood as being opposed to order, and it should not be confused with the metaphorical and colloquial use of the word *chaos.* Rather it describes how order breaks down and reemerges on many levels of complexity within dynamic systems.

Features of chaos theory

There are four essential aspects of CT. First, because of its recursive and iterative character, a chaotic system is exquisitely sensitive to its initial conditions, which means that the slightest variations in the parameters of a system may result in tremendous differences in the system's development. This feature is known as the Butterfly Effect.

Second, within the various modes of a chaotic dynamical system, there are certain levels of stability, especially when movements or changes come to an end. These levels of stability form the mathematical concept of an attractor. The eventual point of rest of a pendulum's movement is an attractor for the mathematical model of the nonchaotic pendulum system. Similarly, in classical thermodynamics the state of maximum entropy can be regarded as an attractor within nonchaotic mathematical models of fluids. Such nonchaotic attractors can be represented geometrically by a single point or a toroid. An attractor is distinguished from a *strange* attractor, the latter being used only in CT. The strange attractor is a fractal, of which the best known are the Hénon, Rössler, and Lorenz attractors. Dynamical systems in chaotic modes stabilize on strange attractors.

Third, the essential difference between the development of a nonchaotic system and the development of a chaotic system has to do with determinism and predictability. Although determinism and predictability are mutually entailing in nonchaotic systems, determinism does not entail predictability in chaotic systems. Chaotic systems possess a certain degree of predictability, measured by the so-called Lyapunov exponent, but all chaotic systems are unpredictable in the long run. Because of this astonishing mixture of determinism and nonpredictability, CT is also called the theory of deterministic chaos.

Finally, in contrast to a nonchaotic deterministic system, a chaotic deterministic system is not reversible due to progressive information loss as the system evolves. Thus, it is not possible to trace a system backwards to its initial conditions. If this mathematical form of CT is applied in physics to open systems that are far from equilibrium, additional features are revealed:

(1) Autopoietic systems, which are self-generating, can be described by CT.

(2) In order for a system to evolve in a chaotic manner, it is necessary constantly to supply it with energy, and the input of energy prevents it from entering a state of stationary equilibrium.

(3) Due to this constant input of energy, chaotic systems can evolve new features, such as those used in certain chemical clocks.

(4) Because chaotic systems are not static, they can adapt to new environmental conditions.

(5) The application of CT to evolving systems that are far from equilibrium requires a refinement of the concept of entropy.

Theological implications

The fact that determinism does not entail predictability in chaos theory means that knowledge of the future of a complex physical system that can be modeled with a chaotic dynamical mathematical system is severely limited in practice. This limitation of knowledge of the future may seem undesirable, but it turns out to be useful when CT is used as a conceptual tool for studying evolutionary and autopoietic systems. If philosophical reasoning is used to relate natural science to theology, then this new distinction between determinism and predictability has to be respected. There are three predominant options when relating CT to theology.

Ontology. The distinction between the mathematical theory of CT and its physical application raises the question of how to relate divine action to CT. If one interprets the eventual unpredictability of CT as an epistemological clue to an underlying openness in nature, as does John Polkinghorne, one can speculate whether the world is open to divine influences by the concept of "divine information input without energy transfer." On the other hand, if eventual unpredictability is judged to be merely an epistemic limitation with no ontological implications, then CT is not immediately useful for interpreting the natural-law-conforming action of an intentional divine being, though Robert John Russell and others have invoked it to explain how divine action at the quantum level might be amplified to macroscopic dimensions.

Autopoiesis. If CT is linked to the theory of autopoietic systems, the independence of creatures is emphasized rather than their dependence on God. This interpretation is adopted in some contemporary kenotic theologies and it tends to challenge traditional theological teachings such as providence and omnipotence. Generally, CT leads to the conclusion that it is more plausible to think of God as a cooperative partner in a panentheistic way, rather than as an almighty ruler, if God is to be thought of as a being at all, which is itself theologically controversial.

Unpredictability. The eventual unpredictability that is intrinsic to CT offers the possibility of reinterpreting the concept of divine providence. Rather than conceiving of God's knowledge as a deterministic prescience, one can interpret that knowledge as a knowledge of different options within an open future that is vulnerable to the possibilities of failure and error. In light of CT, one could also argue that in God predictability and determinism are again fused. This third interpretation does justice to human freedom. The use of CT in neuroscience invites attempts to relate CT's distinction between predictability and determinism to neurological interpretations of human free will. However, the deeper problem is whether mental phenomena, such as the will, can be reduced to neural activity, and here CT seems to offer no new insights.

See also CHAOS, RELIGIOUS AND PHILOSOPHICAL ASPECTS

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CHEMISTRY

When, in the 1830s, eight authors published Bridgewater Treatises on the goodness and wisdom of God, the series included volumes on astronomy and physics, geology, psychology, human physiology, animal and vegetable physiology, zoology, and the human hand. But chemistry was stuffed into a rag-bag of a book by William Prout (1785–1850) that also covered meteorology and the function of digestion. Yet this was a time when lectures on chemistry attracted large and enthusiastic audiences, and chemistry was perceived as a fundamental science. When most science was popularized in a context of natural theology, why was chemistry seen as problematic?

In the early twenty-first century, *chemicals* are perceived as alarming additives, the chemical industry as a source of pollution, and fertilizers, pesticides, and explosives as dangerous to the planet and its populations. Still, people depend upon plastics, synthetic fibers, pharmaceutical drugs, and paints. Chemistry is everybody's service science, ubiquitous, but highly suspect, which points to the reason for its neglect by natural theologians. Astronomers contemplate the starry heavens; chemists understand the world in order to change it.

Chemical theology in history

The alchemist was an optimist, seeing potential gold where others saw dross. Alchemists often identified the perfecting of base metal into gold with the simultaneous spiritual perfecting of the alchemical practitioner. George Herbert's well-known poem *The Elixir* (1633) is indeed used as a hymn. God's creation of the cosmos from chaos was compared to an alchemical project. In the laboratory, the natural improvement of base metals could be accelerated. But in the second half of the seventeenth century Robert Boyle, one of the fathers of modern chemistry, although deeply interested and involved in alchemy, delighted especially in the mechanical or corpuscular philosophy as a basis for natural theology—comparing God to a clockmaker rather than to an alchemist. He and the other founders of the Royal Society favored the plain words of artisans rather than witty metaphysical conceits or coded messages for initiates. The oblique, resonant, and metaphorical language of alchemy gave way, especially in the 1780s in the hands of chemist Antoine Lavoisier, to sober prose approximating as far as possible to algebra. For Boyle, who was deeply devout, mechanical explanations were particularly satisfying and intelligible. He bequeathed money for lectures demonstrating the existence and wisdom of God. For succeeding generations this meant *astrotheology,* joyfully dwelling upon Isaac Newton's work, and *physico-theology,* showing how humans and other creatures were like beautifully designed little clocks living in an enormous clock.

Whereas astronomy was a science of meditative observation and calculation (with spin-offs into calendars and navigation), chemistry was active and practical. The busy chemist's task was to improve the world by isolating metals, distilling medicines, or making ceramics and dyes. Adam and Eve had been expelled from paradise and sentenced to hard labor: Chemists might be able to do something about that. As the macho English chemist Humphry Davy declared in the early nineteenth century, the chemist is godlike because he exerts a "creative energy" that "entitles him to the distinction of being made in the image of God and animated by a spark of the divine mind" (p. 361). Instead of simply commending this best of all possible worlds and its designer, therefore, chemists seek to understand it in order to change it for the better, using God-given intelligence and manual skills.

Chemistry is essentially an experimental science, concerned with the secondary qualities of color, taste, and smell, and demanding trained fingers, hands, and noses; it cannot be done on paper in an armchair in a study or library. When interrogating nature through experiments, the chemist for Davy is not a passive scholar, but a master, active with his own instruments, exerting the "godlike faculties, by which reason ultimately approaches … to inspiration." In the words of a poet, Davy's lectures disclosed "Nature's coyest secrets." Davy was a friend of Samuel Taylor Coleridge and other Romantic poets, and went from interrogation to worship of nature, as we see in his poems and last writings. Such pantheism was not unusual among scientists of the nineteenth century, who found religious experience in communing with nature both in the laboratory and on mountain tops.

The enthusiastic Samuel Parkes, a Unitarian and a chemical manufacturer, borrowing from church teaching called his elementary and successful book of 1806 *The Chemical Catechism*. Not only did he hope that parents would ensure that their children learned chemistry for its utility, he also sought to defend the youthful mind against "immorality, irreligion, and scepticism." The text (questions and answers) was amplified with footnotes, where chemical detail, poetry, and occasional encomia upon the creator were to be found. The "goodness of the ALMIGHTY" was particularly displayed in the various uses to which different substances may be put, though sometimes the "design of Nature" in assigning properties to things was not yet apparent. The book is pervaded with natural theology, rather than being an exposition of it. In a later popular work *The Chemistry of Common Life* (1855), widely known in translation as well as in English, the Presbyterian James Johnston concluded surprisingly that earthly life was insignificant in the vast general system of the universe. Humans were here solely because God, in a separate act of will, had formed beings to admire God's work. Johnston sought thus to indicate the insufficiency of natural theology without revelation, which told more of God's purposes and character than could ever be inferred from chemical discoveries.

Authors of Bridgewater Treatises were meant to confine themselves to natural theology, and Prout's was thus a straightforward exposition of the design argument, given a particular turn because of his idiosyncratic atomic theory. But chemistry was making rapid progress, and in 1844 George Fownes published his book *Chemistry as Exemplifying the Wisdom and Benevolence of God,* which was awarded the Actonian Prize associated with the Royal Institution, where Davy and Michael Faraday held forth. Fownes began from the position that recent studies (especially with microscopes, enormously improved at this time) had shown how exquisitely animals were adapted to their environment. Then he declared that recent discoveries in chemistry, especially in its organic branch, made it easier to use science to infer design. He urged people to look for God's activity in the commonplace and the everyday world, seeing God's hand in the simple laws of chemical combination, the ubiquity of protein, and the equilibria among reversible reactions that made animal and plant chemistry possible. Natural theology was for Fownes the highest aim of science. His book is also a good account of the current state of chemistry, being transformed at that time through the work especially of Justus Liebig, in whose wake German universities were training large numbers of professional research chemists to work in industry and academia.

Both Prout and Fownes came under friendly fire from George Wilson in his *Religio Chemici* (published posthumously in 1862) for their Panglossian emphasis upon unmixed and unbounded benevolence. Wilson, the first Professor of Technology in Edinburgh University in Scotland, was dogged by bereavements and illness, but supported by staunch religious faith. He believed that while chemical evidence, especially from the earth's atmosphere and the carbon and water cycles, demonstrated design, the demonstration of benevolence was another story. Introducing a gendered perspective, he noted that men read the Bridgewater Treatises and such books chiefly to learn science; women, more perceptive, did not because they were not impressed by such banal optimism. The problem of evil was real, and the dark side must be faced. If human bodies are constantly being renewed, why then do they wear out? Why are there poisons? Wilson noted the formidable weapons of destruction possessed by carnivores—"God has been very kind to the shark"—and the reality and enduring character of pain, animal and human. Evil exists alongside good, and cannot in the manner of the Manicheans be separated from it. Chemistry can show that God *has* love, but not that God *is* love. For Wilson the problem of evil is real and cannot be solved in this world, except in the light of revealed religion and true conversion. Astrotheology might be immune from such criticisms, but physico-theology along with reasoning from chemistry is undoubtedly undermined. Most of those writing natural theology had been, like William Paley, healthier and wealthier than the average person, and Wilson brought in a draft of fresh air.

The twentieth century onwards

Natural theology had made popular chemical books and lectures interesting and indeed momentous. By 1900, however, there were many students (more than in any other science) with examinations to pass and professional qualifications to gain, and their textbooks had become much drier and more factual, presenting chemical theory but not a worldview. Also, natural theology was in retreat for most of the twentieth century, under assault not only from scientific naturalists but also from theologians. And whereas chemistry had seemed a fundamental science to Davy and his contemporaries, in the early twentieth century it appeared that chemistry was being reduced to physics with the work of Ernest Rutherford and Niels Bohr. No doubt experiment was still necessary because the mathematical equations, based upon quantum theory, were too difficult to solve in detail, but genuine chemical explanation would in principle be in terms of physics, or so it seemed to physicists, who enjoyed enormous prestige. Philosophy of science, therefore, was for much of that century focused upon physics; chemistry seemed necessary, but not exciting. In addition, much nineteenth-century research had been done by individuals. In the twentieth century, the teams and groups that now undertook scientific research needed to include a chemist or two whatever their field, but the glamorous science was physics. Then came the elucidation of the DNA structure, making molecular biology and genetics major areas of interest; here, as in pharmacy, chemistry was essential, but still not the center of interest for the lay person following what was going on. In the United States, Creationism focused the attention of natural theologians upon Charles Darwin's theory of evolution by natural selection, which by the second half of the century incorporated genetics. Only perhaps in the context of ecotheology has chemistry again impinged seriously on religious thinking.

Nevertheless, chemistry was not really reduced to physics any more than architecture has been; builders must take into account the law of gravity, and chemists building molecules cannot defy the laws of physics. Working within such constraints is the basis of art in both fields. Roald Hoffmann emphasizes the creativity that lies behind structural chemistry, designing substances never made before. He also draws attention to the visual and verbal language of chemistry and the role of illustration in the science. Lavoisier's project of abolishing richness has not been achieved, and chemistry can be fun. Hoffmann has also been involved with Shira Schmidt in reflection on Jewish traditions in the light of chemistry, seeing argument as central to both and exploring dichotomies between natural and artificial, symmetry and asymmetry, purity and impurity. This is not the traditional enterprise of natural theology, as in Fownes's book, but much less formal. For the believer, satisfying parallels and analogies reveal themselves in a coherent pattern, and metaphors are refreshed.

A collective study of *Science in Theistic Contexts* (2001) unsurprisingly contains no discussion of chemistry. In their Gifford Lectures, however, published as *Reconstructing Nature* (1998), John Brooke and Geoffrey Cantor investigate the engagement (a useful word with multiple meanings) of science with religion in a historical perspective. They devote a chapter to chemistry, with particular discussion of the theological problems that can arise from the idea that the chemist is perfecting creation. They see process as a feature of chemistry that might bear upon religion. Most people accept that a world with nylon and aluminum is better than one without, and expect more progress in applied chemistry, but people remain uneasy about nineteenth-century chemist Eleanor Ormerod's enthusiastic espousal of chemical pest-control, with its aim of exterminating noxious insects. Brooke and Cantor also look at materialism and reductionism, in which chemistry has been involved—the melancholy may be bracingly told "it's just your chemistry," and may or may not find that consoling.

What emerges is that chemistry has never been nearly as tempting for the natural theologian, wishing to put design beyond reasonable doubt, as astronomy or natural history. While the world of stinks and bangs is fun, atoms and molecules lack sublimity or accessibility. Chemistry is not only the experimental science par excellence, it is also useful in seeking to improve the world and the quality of life. That, and the idea of process, is something that should resonate with anyone pursuing natural theology, especially in an intellectual climate where the argument from design runs up against a deep prevailing skepticism. In such a broader and more sensitive natural theology, there should also be room for the metaphors and analogies from chemistry that can make it aesthetically, rather than logically, compelling.

See also ALCHEMY; DESIGN; DESIGN ARGUMENT; ECOLOGY; ECOTHEOLOGY; NATURAL THEOLOGY

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DAVID M. KNIGHT

CHINESE RELIGIONS AND SCIENCE

The three main *Jiao* (systems of teachings and beliefs) in Chinese tradition are Confucianism, Daoism, and Buddhism, which are called the "three religions." However, Chinese scholars generally consider Confucianism, the School of Daoism (*Dao Jia*), and the School of Buddhism (*Fu Jia*) to be philosophies, whereas Daojiao (*Jiao* of Daoism) and Fujiao (*Jiao* of Buddhism) are considered to be religions. In the West, all are regarded as either religions or philosophies or both.

In regard to Chinese science, traditional Chinese scientific discoveries should not be measured by the standards of modern Western science. By doing so, one risks missing many of the real merits in non-Western cultures. One example is that the holistic view and the harmony of the *yin-yang* (shade and sunshine) concept of the human body and soul in Chinese medicine does not correlate directly with the standard Western (Greek) dichotomy of body and soul, although many have tried to make this correlation.

The main themes of traditional Confucianism are to cultivate the person, to regulate the family, to effectively govern the state, and to exemplify virtue throughout the world. The purpose of science and technology is to help a person be a good politician and sage. Moral teachings are considered far more important than scientific findings. Confucianism does not oppose scientific and technological knowledge; the attitude of Confucianism toward science is to leave it alone.

Daoism as a religion can be traced back to ancient China, especially to the philosophers Lao-tzu (c. 604–490 B.C.E.) and Chuang-tzu (c. 399–295 B.C.E.), although Daoist teachings were later radically reinterpreted. Later Daoism is called *Daojiao* (Daoist religion) rather than *Daojia* (School of Daoism), the name for classical Daoism. The Daoist religion sought to lead its adepts into such a harmonious relationship with the world that they would escape the horrors of disease and the tragedy of death. It was not life after death that they sought, but life without death, which they tried to achieve through the use of drugs, meditation, exercise, appropriate sexual activity, and purity of life. These approaches to immortality led to the development of traditional Chinese sciences, which include Chinese medicine, pharmacology, chemistry, and health care techniques. Traditional Chinese science also includes efforts to exploit the outside world in order to find a place for immortals to live. Such efforts constitute the earliest Chinese geographical work.

Buddhism was introduced to China around the first century B.C.E. In order for assimilation to take place, Buddhism had to undergo a process of contextualization in China. Chinese Buddhists declared that Buddhism is different from Daoism. In *The Emptiness of the Unreal,* the Buddhist philosopher Seng Chao (384–414) pointed out that Daoism teaches belief in *wu* (nothingness), which is a metaphysical reality. Buddhists, however, believe in *sunya* (emptiness), which is the negation of any kind of independent reality. Seng Chao also taught that all existences are conditioned by necessary causes and sufficient causes; there are no eternal realities in themselves. He quotes from the teaching of Buddha to assert "no life and no death, no continuousness and no discontinuousness. No universal and no particular, no come and no go … this is the first truth of Buddha." The basic teaching of Buddhism is to release human beings from suffering, which comes from desire. Buddhists strive to leave this world by entering the realm of *nibbana* or *nirvana,* where all the activities of the mind stop. From this point of view, Buddhism contributes little to science in Chinese culture.

See also CHINESE RELIGIONS, CONFUCIANISM AND SCIENCE IN CHINA; CHINESE RELIGIONS, DAOISM AND SCIENCE IN CHINA; CHINESE RELIGIONS, HISTORY OF SCIENCE AND RELIGION IN CHINA

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CHINESE RELIGIONS, CHINESE BUDDHISM AND SCIENCE

See BUDDHISM; BUDDHISM, CONTEMPORARY ISSUES IN SCIENCE AND RELIGION; BUDDHISM, HISTORY OF SCIENCE AND RELIGION

CHINESE RELIGIONS, CONFUCIANISM AND SCIENCE IN CHINA

The term of *Confucianism* is ambiguous. It refers to the ideology developed by a man named Confucius (522–479 B.C.E.), but Chinese scholars prefer to use the term *Rujia,* which means the school or teachings of the scholars. *Ru* was originally used to refer to dispossessed aristocrats of antiquity who were no longer warriors, but lived according to their knowledge of rituals, history, music, arithmetic, and archery. The term eventually became a designation of honor. The "school of *ru*" eventually came to encompass the ethical wisdom of the past that Confucius transmitted to later ages, as well as the entire development of the tradition after his time. In this sense, it constitutes the "religion" of the Chinese because it provides a system of beliefs and values that calls for faith and acceptance from adherents. It also qualifies as a religion in that it provides a way of life for adherents to follow, rather than a body of knowledge for them to master. In this regard, Confucianism is more comparable to Western religions than it is to Western philosophies. However, Confucianism is not a religion in the Western sense because it has no transcendental God, no eschatology or teaching beyond this life, and no organizational structure. It is only a teaching, and it teaches people how to live a noble life in a particular social context.

The teaching of Confucianism

The main teaching of Confucius is *jen,* which literally means "two persons." *Jen* is concerned with human relationships and with the virtue of the superior or noble person. *Jen* is associated with loyalty (*zhong*), referring basically to loyalty to one's own heart and conscience, rather than to a narrower political loyalty. *Jen* also refers to affection and love. The great Confucian thinker Mencius (371–289 B.C.E.) said, "The human being of *jen* loves others." However, *jen* should be guided by *yi* (righteousness), and a superior person must know how to love others and when not to love others. The Confucian interpretation of *jen* as universal love differs from that of Mo-tzu (fifth century B.C.E.), who advocated a love for all without distinction. The followers of Confucius emphasize the need of discernment, of making distinctions, and they reserve for parents and kin a special love. Familial relations provide a model for social behavior by which people should respect their own elders, as well as other's elders, and be kind to their own children and juniors, as well as those of others. This is the reason for the strong sense of solidarity not only in the Chinese family, but also in Confucian social organizations among overseas Chinese communities.

Ritual is an important part of Confucius's teachings as well, and Confucianism is also known as the ritual religion (*li-jiao*). Confucian teachings have helped keep alive an older cult of veneration for ancestors and the worship of heaven. This was a formal cult practiced by China's imperial rulers, who regarded themselves as the keepers of "Heaven's Mandate" of government, and were considered to be "High Priests," mediators between the human order and the divine order.

Before the twentieth century, the calendar of official sacrifices was determined by the Board of Astronomy according to established divinatory procedures and was published well in advance by the Ministry of Rites (*li-Pu*). During the last dynasty (Q'ing, 1644–1912), the Ministry of Rites performed the same functions as they did during the Han dynasty (206 B.C.E.–220 C.E.). The Ministry's most important responsibilities were educational, but it also kept records of all ceremonies the emperor attended, of the descendants of Confucius, and of Buddhist, Daoist, medical, and astronomical officials. All cases of filial piety, righteousness, and loyalty were reported to the emperor for rewards.

Neo-Confucianism

Neo-Confucianism develops the meaning of *jen* through the School of Mind. Wang Yang-ming (1472–1529) understood that the *hsin* (mind and heart) was the root of *jen,* according to which *hsin*-in-itself is the highest good. It exists beyond good and evil to distinguish what is good and evil. This is the substance of morality. Yang-ming called it *liang-chih* (inborn capacity to know the good) and *liang-neng,* which enables one to act according to one's originally good nature. When the mind is in good condition, for example, no human desire occupies it and the mind is clear and intelligent. If one has a clear and intelligent mind, one knows how to apply moral principle to daily life. It does not matter if one is versed in technical knowledge or knows how to complete a task. As Yang-ming puts it, if a person knows what filial piety is, that person will know how to treat his parents well.

Yang-ming does not distinguish between moral knowledge and cognitive knowledge, with the result that in Confucianism, moral knowledge suppresses cognitive knowledge. Contemporary neo-Confucianists understand this, and have revised Yang-ming's theory by stressing cognitive knowledge so as to open the door to modern science and democracy.

Confucianism and science

Traditional Confucianism valued science mainly for its practical applications. Astronomy and mathematics, for example, were valuable for divination and agricultural purposes. Both of them were also needed in making calendars, which were important for the agricultural economy. In addition, Chinese medicine was an early scientific tradition with many practical applications related to the surival of human beings.

Astronomers were active during the East Chou period (722–222 B.C.E.) in China. Almost all Chinese astronomers were also astrologers. They believed that the stars and celestial bodies affected the governmental bureaucracy, but seldom affected individuals or the population in general. The *Shiji* (Records of the historian), written by Sima Qian in 90 B.C.E. during the Han dynasty, includes a systematic chapter on astronomy. The chapter reviews the stars and constellations of the five "Palaces" (circumpolar, east, south, west, and north) and includes an elaborate discussion about planetary movements, including retrogradations, followed by the astrological association of the lunar mansions with specific terrestrial regions, and the interpretation of unusual appearances of the sun and moon, comets and meteors, clouds and vapors, earthquakes, and various harvest signs. The author also warns the emperor to pay attention to astronomy because it can help him learn how to govern the empire.

The most important early writing on mathematics is *Jiuzhang suanshu* (Nine chapters on the mathematical arts), written in 260 C.E. by Liu Hui. This work provides the first Chinese geometrical proofs in connection with finding the areas of a trapezium (a quadrilateral formed by two isosceles triangles) and other figures. The first chapter of *Jiuzhang suanshu* is a "Land Survey" that gives the correct rules for finding the areas of rectangles, trapeziums, triangles, circles, and arcs of circles and annuli. The second chapter, "Millet and Rice," deals with percentages and proportions, and reflects the management and production of various types of grains in Han China. The sixth chapter, "Impartial Taxation," deals with problems of pursuit and alligation, especially in connection with the time required for people to carry their grain contributions from their native towns to the capital.

Nearly one thousand Chinese mathematical treatises from the second century C.E. onward survive. The great majority have to do with the kinds of practical matters that government officials, their clerks, and landowners would encounter, such as surveying land and calculating exchange rates and taxes payable in money and commodities. The predominantly practical orientation of Chinese mathematics makes it neither inferior nor superior to the Western tradition. Its lack of development at the abstract geometric level was balanced by its strength in numerical problem solving.

Another important function of mathematics in premodern China was divination (*shu*) and astrology (*suan*), both of which included numerology. Some divination techniques also identify regularities underlying the flux of natural phenomena.

In general, Confucianism is mainly concerned with ethics, morality, and political theory rather than science and technology. Although Confucianism essentially functioned as the state religion, it was conspicuously un-religious. Confucian scholars who lived during the long period (approx. two thousand years) of unity of Chinese society always set the social agenda concerning how to "cultivate their persons, regulate their families, govern well their states and finally exemplify illustrious virtue throughout the world" (c. fifth to first century, *Great Learning*). The purpose of science and technology in a Confucian society is to help a person to be a good politician and sage. Thus, moral teachings are more important than natural scientific findings, and scientific discourse in Chinese culture tends to be full of speculations and metaphors, rather than accurate factual information.

Confucian tradition has not been concerned with scientific theory, so traditional Chinese sciences have focused on practical applications in medicine, agriculture, arithmetic, and astronomy. Traditional Chinese sciences have also stressed the political and moral implications of science and technology. Nonetheless, Chinese scientists are credited with some important inventions, including paper, the compass, the art of printing, and the production of gunpowder. Although the compass was invented in China around 2700 B.C.E., there was no further scientific theory of the compass. The Chinese people used compasses mostly for determining *Feng Shui* (wind and water), a folk superstition by which people set up a comfortable living environment. Although it can not be denied that technical investigations were fruitful in Chinese history and resulted in many inventions, scientific theorization remained on the level of factual description and empirical interpretation. For example, traditional Chinese medicine involves a great deal of speculation that is not supported by clinical experimentation; it remains on the level of abstract thinking and intuitive observation. Arithmetic was also mainly used for practical calculation that did not require abstract thinking, so no mathematical theory or formal logical system was developed.

Under the ideology of Confucianism, science and technology had to deal with daily issues of human society, and Confucian scholars made little effort to engage in scientific and technological research. Science and technology were generally regarded as merely a means for human beings, with no ultimate value in helping someone become a sage. This may be one of the main drawbacks of the Confucian value system and worldview: It has served as a drag on Chinese scientific and technological development.

See also CHINESE RELIGIONS AND SCIENCE; CHINESE RELIGIONS, HISTORY OF SCIENCE AND RELIGION IN CHINA; MATHEMATICS

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CHINESE RELIGIONS, DAOISM AND SCIENCE IN CHINA

As the native religion of China, Daoism (also spelled Taoism), together with Confucianism and Buddhism, comprises the main body of traditional Chinese culture. Daoists, in pursuit of the ideal of becoming immortals by practicing *Dao,* made great efforts to transcend conventional wisdom about life and knowledge and so helped both to define ancient science in China and to advance it through a great number of inventions.

Relationship between Daoism and science

For a long time, many Western translators, writers, and scholars misunderstood Daoist thought, largely overlooking its scientific and protoscientific aspects. Moreover, different understandings of what constitutes science have rendered the issue more confusing. While some scholars denied any link between Daoism and science, many studies have confirmed an important relationship between them.

Daoist thought is basic to Chinese science and technology. Daoism provided a philosophical foundation for the development of science; its love for nature, its conception of change, its unique mastery of the relationship between human beings and nature, and its pursuit of freedom are based on the exploration of nature. Daoist admiration for ancient scientific inventors, and their absorption of science and technology in history, show that Daoism tried to reach its religious ideal by means of science. In addition, Daoism's cultural structure is favorable for science. The unique Daoist ideal of material immortality is invaluable in stimulating the observation and exploration of nature and life, and the development of techniques of alchemy, medicine, and related fields.

Daoists regard Dao as the origin of all things, including human beings, and they believe that people can return to Dao and thus attain immortality. Because immortality can be acquired through learning, one's life rests with oneself rather than heaven. Daoist scriptures include such sayings as "Probe into the mystery of heaven and earth and understand the root of creation" (*The Taoist Canon,* Vol. 18, p. 671). In fact, such explorations serve the goal of achieving oneness with the Dao, which leads to becoming an omniscient and almighty immortal, a True Human of True Knowledge.

Unrealistic as immortality is, many Daoist ideas, techniques, and practices for longevity are reasonable and scientific. They constituted the most important part of Daoist spiritual heritage in the Middle Ages. Thus, Joseph Needham argues in *Science and Civilization in China* (1956) that Daoism "developed many of the most important features of the scientific attitude, and is therefore of cardinal importance for the history of science in China" (vol. 2, p.161). Similarly, Welch Holmes writes in *Taoism: The Parting of the Way* (1957) that "the Daoist movement has sometimes been called the Chinese counterpart of Western science … To a large extent the Daoists practiced experimental science" (p.134).

Daoist contributions to science

Hua Tuo, a famous Daoist doctor in the third century C.E., was the first to use a type of anesthesia called *ma fei san.* He also formulated the gymnastic techniques called *wu qin xi* (imitation of five-animal playing) for nourishing vitality of life. A text of Daoist prescription *Zhou Hou Bai Yi Fang* (Collection of prescriptions for hundred-and-one diseases fourth century C.E.), written by Ge Hong and enlarged by Tao Hongjing, contains the first known record of the disease of smallpox. It also records therapeutic techniques for dealing with a variety of acute medical conditions, including artificial respiration, bleeding stoppage, abdominocentesis, catheterization, clyster, intestinal anastomosis, *débridement* (sore cleaning), drainage, fracture treatment with superficial fixture, and disjointed articulation restituting. Remarkably, this work recorded an anti-malaria treatment using southernwood (*Artemisia annua* L.). In the 1970s, scientists extracted artemisinin from southernwood, which is a significant discovery in the history of antimalaria treatments from medicines of the quinoline category. Sun Simiao, a great Daoist doctor, summed up in the seventh century C.E. the prevention of struma by using animal thyroid and the prevention of nyctalopia by using animal livers. And the treatment of restituting mandible disjointing that Sun Simiao put forward is still in use in modern medicine. *Jin Si Xuan Xuan* (The incredible mysteries in the golden box), a Daoist text of parasitology written sometime between the fourteenth and seventeenth centuries C.E., enumerated a "Catalogue of Nine Parasite Species" with illustrations of various kinds of parasites, as well as figures depicting their life cycles.

In seeking elixirs from the bodies of human beings themselves, Daoists made great strides in the field of biochemistry. Both Joseph Needham and Lu Gwei-Djen hold that the medicine named *qiushi,* which was made by medieval Daoists, is a relatively pure preparation of urinary steroid hormones. A similar medicine was made in the West by a German biochemist in the early twentieth century.

Daoists also acquired solid knowledge of certain chemical reaction processes. They accurately described the reversible reactions between mercury and thiosugar. *Long Hu Huan Dan Jue* (The oral formula for cyclically transformed elixir of dragon and tiger), written by Jin Ling Zi, an expert in alchemy in the Tang Dynasty (618–907), recorded precise methods of making arsenic-copper alloy and of extracting pure copper, methods developed by Daoists over many generations. Instead of conforming to an older Daoist tradition of keeping key links secret or of using obscure terminology, this text clearly and definitely states strict rules of operation that are similar to those of modern chemistry.

As the basic components of gunpowder in ancient China were niter, sulfur, and carbonaceous substances, all frequently used in Daoist alchemical experiments, the invention of gunpowder can be traced back to Daoist writings in the Han Dynasty (206 B.C.E.–220 C.E.). The formula included in *Bao Pu Zi Nei Pian* (The inner chapters of the Philosopher Master-Who-Embraces-Simplicity), written by Ge Hong in the fourth century C.E., already covered the basic composition of gunpowder. In the middle of the ninth century C.E., the Daoist scripture *Zhen Yuan Miao Dao Yao Lue* (Classified essentials of the mysterious Tao of the true origin of things) clearly recorded the precise composition of gunpowder. Obviously, the time of its invention was much earlier.

Many Daoists were also metallurgists. The hydrometallurgical technique of smelting copper from cupric sulfate liquor was first used in China in Daoist alchemic practices. It can be traced back to *Huai Nan Zi* (The book of Master Huainan), a Daoist text written in the early years of the first century C.E., it formally appeared in Daoist texts of the Tang Dynasty, and it became the prevailing technique of copper production during the Song Dynasty (960–1279). It was no later than the Song Dynasty that Daoists had identified the element arsenic and extracted pure samples of it. Around the year 550 C.E., a Daoist practitioner invented a technique of steel production called *guan gang fa,* by which pig iron and wrought iron were heated together to a certain temperature for higher quality steel. With its moderate carbon content, this kind of steel was ideal for making high-quality tools. This technique was widely used and refined in China during the succeeding one thousand years.

With seven kinds of materials, Daoist alchemists created the earliest fireproof sealing material called *six-one mud.* They made glass and preserved valuable technical data in their writings. They wrote works on casting techniques such as *Shen Xian Lian Dan Dian Zhu San Yuan Bao Zhao Fa* (Spot casting methods of bronze mirror of the three origins of things by the immortals), in which they recorded in detail the techniques of quality control in casting. Ever since *Huai Nan Zi* in the Han Dynasty, Daoists used mercury-tin alloy and later added lead amalgam to create an ideal media for bronze mirror polishing.

A technique involving the suspending of magnetized needles was used by Daoists to test the quality of lodestone, which was a major healing object in alchemy. Eventually, this technique led to the invention of the magnetic needle compass. In addition, modern scientists found that *Wu Yue Zhen Xing Tu* (Maps of the true topography of the five sacred mountains), drawn in the third or fourth centuries C.E. and treasured by Daoists over the last eighteen centuries, contains the earliest type of contour map. The maps roughly reflect the local terrain and routes of the mountains.

Precise clock devices are of great importance in Daoist practices. Throughout Chinese history, many Daoists participated in the invention and improvement of the water clock. The famous *cheng lou,* a scale-controlled water clock invented by a Daoist named Li Lan, was widely used in the 400 years between the fifth and eighth centuries C.E., and served as an important component of various types of compounded clock devices in China. It was also used in the medieval Islamic world; studies show that Muslims probably learned about such clocks from the Chinese. Daoists of the Quanzhen Sect even invented portable water clock devices. A scripture called *Quanzhen Zuo Bo Jie Fa* (Quanzhen Sect easy preparation for sitting quiet in meditation), written between the tenth and fourteenth centuries C.E., recorded the technical details of making, debugging, and controlling the clocks.

Zhang Zhihe, a Daoist who lived during the Tang Dynasty, expounded the phenomenon of duration of vision, as it was called in modern optics. Later, another Daoist, Tan Qiao, who lived during the Five Dynasties (907–960), discussed the phenomenon of reflection of plane mirrors. Zhao Youqin, a Daoist of the Quanzhen sect who wrote the famous scientific work *Ge Xiang Xin Shu* (*New Book on the Investigation of Astronomical Phenomena*) in the Yuan Dynasty (1260–1368), conducted a series of large-scale experiments on geometric optical problems, such as rectilinear propagation of light, hole imaging, and intensity of illumination. He came to correct conclusions in these fields two centuries earlier than Galileo Galilei (1564–1642). His rough conclusion that "illumination intensifies as the intensity of light source enhances, but decreases as the image distance increases" appeared four hundred years earlier than Lambert's formula of qualitative illumination published in 1760, according to which "illumination is in reverse proportion to distance squared." In the early years of the nineteenth century, there were still Daoist believers in Guangzhou who studied with an open mind both the traditional Daoist theory of sphere-heavens and modern European astronomy.

In order to avoid losses in their alchemical experiments and for many other religious purposes, Daoists conducted weather observation and forecast. Their scripture *Yu Yang Qi Hou Qin Ji* (The near forcasting of the weather of rain or fine) analyzed scientifically the causes of wind and rain and recorded in terse but vivid verses their observations, which conform with modern meteorological science. They even provided various types of "cloud pictures" in the text.

Daoists not only explored but also wanted to navigate the heavens. The "flying vehicle made of jujube heart timber," recorded by Ge Hong in his *Bao Pu Zi Nei Pian* and regarded as the earliest design for a propeller aircraft, reveals the Daoist knowledge of the aerodynamic principles of flight. Modern scientists have recreated the vehicle according to Ge Hong's records and testified it to be technically reasonable. Ge Hong added that when rising to a height of forty *li* (about 12.44 miles) into the heavens, one can reach the outer space of *taiqing* (super clarity), where the air is powerful enough to support flying objects, helping them to fly naturally by inertia instead of motive forces. This is close to the law of First Cosmic Velocity in the modern science of astronautics. In the fourth century C.E., a hermit Daoist named Wang Jia wrote *Shi Yi Ji* (Record of gleaning), in which he claimed that once there had been a huge space aircraft named *Cha* ridden by the immortals. This aircraft used the sea as its base for launching and landing, and it continually navigated around the four seas, making a circuit every twelve years.

With the invention of gunpowder and the subsequent emergence of applied techniques for the control of its explosive power, the idea arose of using it as a rocket propellant. In the fifteenth century, an official of the Ming Dynasty named Wan Hoo conducted and died in the first attempt at manned rocket flight in human history—propelled by forty-seven gunpowder rockets. A Daoist biographical text formally printed in 1909 includes a description of a Daoist beauty who launched her aircraft into the heavens from a silo by means of a propellant compounded from cyprinoid fat.

Daoists were responsible for rich scientific achievements in many other fields, including cosmology, uranography, calendar making, geography, geology, mineralogy, botany, zoology, pharmaceutics, architecture, porcelain production, dye making, wine making, zymurgy, cerebral science, acoustics, wushu, sex hygiene, strategics, and psychology. Because the impetus for scientific exploration comes for Daoists from their religious belief in immortality, their science was inevitably bound by the ideas, purposes, and the historical development of Daoism. Therefore, it was impossible for science to gain an independent and deep development within the Daoist framework. Yet the remarkable achievements of Chinese science were also enabled and inspired by the Daoist interpretation of reality.

See also DAO

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JIANG SHENG

CHINESE RELIGIONS, HISTORY OF SCIENCE AND RELIGION IN CHINA

The terms *religion* and *science,* which were introduced to China in the seventeenth century by Jesuit missionaries, are controversial in a Chinese context. *Religion* in Chinese is *jiao* (systems of teachings and beliefs); in this sense, Chinese religions include Confucianism, Daoism, Buddhism, and the religions of antiquity. Whether Confucianism has a religious dimension is debatable, but Daoism certainly qualifies as a religion. Since Buddhism came from India, its religious character is quite different from those of Confucianism and Daoism. As for the term *science,* the very notion of a "Chinese science" is problematic. The modern concept of science cannot be used to measure ancient Chinese ideas, theories, studies, or inventions because doing so would misrepresent the merits of traditional science in Chinese culture. It cannot be denied that there were great inventions in ancient Chinese history, including gunpowder, the compass, paper making, and the art of printing. However, these inventions did not lead to modern scientific discoveries, and thus there is a gap between traditional Chinese science and modern Chinese science. In fact, modern Chinese science has been a recent development in response to the Western world.

Religion and science in ancient China

During the Shang dynasty (1766–1122 B.C.E.), ancient Chinese people believed that their ancestors, upon death, would continue to exist in heaven, the home of the divine ruler or lord on high (*Shang-ti*), and from heaven they could influence human affairs. According to oracle bones that were discovered at the end of the nineteenth century in Anyang in northern China, Shang-ti watches over human society and regulates the workings of the universe. In view of the close relationship between religious worship and family clans, it is possible that Shang-ti was the chief god of the ruling family clan. Thus, the ascendancy of Shang-ti in religion closely parallels the political ascendancy of the family clan that practiced the cult of Shang-ti. Beneath him are a number of lesser deities of the sun, moon, stars, wind, rain, and particular mountains and rivers.

The oracle bones, which were made from tortoise shells or the shoulder blades of oxen, bore inscriptions written by the Yin or Shang people for purposes of divination. Yin people believed that dead animals had the power to contact divine figures, including the ancestors of humans, in the spiritual world. Divination rituals were performed by three groups of functionaries: persons who posed the questions; persons in charge of the ritual itself, which included cracking the oracle bones with heated bronze rods or thorns; and persons who interpreted the resulting patterns of the cracks. In the case of royal divination, official recorders or archivists also took part. After the fall of the Shang dynasty, people who lived during the early years of the Chou dynasty (1122–1249 B.C.E.) continued to practice divination using shells and bones, then the practice died out.

Divination presupposes a belief in spirits and their power to protect the living. Ancient Chinese people believed that the cosmos consists of three levels: heaven above, the dwelling place of the dead below, and the Earth in between them. When people die, the "upper soul" (the psyche) rises up to heaven while the "lower soul" (the physical body and emotions) descends to the underworld. Ancestors of the royal family were considered to be the most powerful among the dead on account of their special relationship with the gods. It was believed that they dwell in high heaven in the company of the gods, where they continue to have power over the living, either to protect and bless them or to punish and curse them.

From the inscriptions on oracle bones, scholars know not only the divination activities but also the scientific activities of Yin people. Oracle bones record eclipses and novae, as well as names of stars and constellations. They show that Yin people used a lunar calendar with twelve *yues* (moons or lunar months) in one lunar year. Each lunar month consisted of twenty-nine or thirty days, and every two or three years one extra month, known as the intercalary month, was added to keep the lunar year in step with the corresponding solar year. Numerals found on oracle bones also indicate that Yin people used a decimal system.

In the Warring States period (480–381 B.C.E.), the disciples of Mo Zi (479–381 B.C.E.) made great contributions to natural science, especially in the areas of statics, hydrostatics, dynamics, and optics. Mohist physicists understood that light travels in straight lines. By using fixed light sources, screens with pinhole apertures, and possibly the camera obscura, they were able to study the formation of inverted images and the idea of the focal point.

Confucianism

Confucianism is the English word for *Ru-jia* (School of Scholars), which was founded by the philosopher and teacher Confucius (551–479 B.C.E.). The name *Confucius* is the Latinized form of *Kong Fu-tzu,* a respectful way of addressing the master. *Kong* was his family name. Confucius lived in a time when the empire was fragmenting into numerous feudal states. It was a time of change, disorder, and degeneration of the traditional moral and political order. Confucius can truly be said to have molded Chinese civilization to a great extent. The central concept of his teaching is *jen,* a word that literally means the relationship of two persons, and Confucius's teachings focus on human interpersonal relationships. It is a humanistic approach to philosophical thinking. *Jen* is associated with loyalty (*zhong*), that is, loyalty to one's own heart and conscience. *Jen* is also related to reciprocity (*shu*), that is, respect of and consideration for others. Confucius did not care to talk about spiritual beings or even about life after death. Instead, he believed that human beings "can make the Way (Dao) great," and not that "the Way can make man great" (*Analects* 15:28). Although his teachings concentrate on human beings, Confucius's primary concern is good society based on good government and harmonious human relations. To this end he advocated a good government ruled by virtue and moral example rather than by punishment or force. His criterion for goodness is righteousness as opposed to profit. It is the ideal of a sage or a superior person to apply this inner morality to the outside world. Such an approach is called *nei-sheng wai-huang,* or sagacity within and kingliness without. The opposite of a sage is an inferior man.

The Confucian sage does not withdraw from the business of the world. In his inner sagacity, he accomplishes spiritual cultivation; in his outward kingliness, he functions in society. It is not necessary for the sage to be the actual head of the government in his society. From the standpoint of practical politics, a Confucian sage usually had little chance of becoming the head of the state in Chinese history before the twentieth century. The saying "sagacity within and kingliness without" means only that he who has the noblest spirit should, theoretically, be king. A student of Confucius once asked him: "If a ruler extensively confers benefit on the people and can bring salvation to all, what do you think of him? Would you call him a man of humanity?" Confucius replied: "Why only a man of humanity? He is without doubt a sage. Even Yao and Shun [legendary emperors before the Shang dynasty] fall short of it. A man of humanity, wishing to establish his own character, also establishes the character of others, and wishing to be prominent himself, also helps others to be prominent. To be able to judge others by what is near to ourselves may be called the method realizing humanity" (*Analects* 6:28).

Confucianism emphasizes not just social behavior. It confers definite importance on rituals, including religious rituals, and has even been called a "ritual religion" (*li-jiao*). The Chinese word for *ritual* is related to the word *worship* or *sacrificial vessel* with definite religious overtones. The Confucian emphasis on political responsibility explains why during much of Chinese history Confucianism served the function of a civil religion. From the Han dynasty (206 B.C.E.–220 C.E.) on, an elaborate state cult was developed. It has been, rightly or wrong, attributed to Confucian teachings, which include expressions of very ancient beliefs in a supreme deity.

Daoism

Daoism as religion can be traced back to ancient China, especially to Lao-tzu (c. 604–490 B.C.E.) and Chuang-tzu (c. 369–286 B.C.E.). However, the Daoists reinterpreted the teachings of their religion radically in later centuries. In the third century C.E., the first legendary emperor of ancient China, Huang-di (the Yellow Emperor), was worshiped together with Lao-tzu as Huang-Lao in a cult that involved pursuing immortality and changing base metals into gold. From that time on, the Daoist religion identified with the quest for immortality, including physical immortality, through the search for elixirs in alchemy and through yogalike exercises. Elixirs frequently contained toxic compounds derived from mercury, lead, sulfur, arsenic, and so on, certain to cause poisoning. If metallic poisoning might bring death, there was also the hope that such death was temporary, as a necessary phase in the quest for eternal life. Although mercuric and lead compounds can be fatal when swallowed, they are also known to have preservative powers. It may be that Daoists believed the power of faith would protect their physical bodies from corruption, so that their souls would remain with their bodies and eventually attain immortality together.

The strong idea of elixir alchemy for eternal life contributed to traditional Chinese medicine, while yogalike exercises contributed to health care. Yoga techniques are based on the theory of interaction between body and spirit and the possibility of controlling one's mental state by manipulating one's body.

Daoism, according to some scholars, is *the* folk religion of Chinese people. Unlike Confucianism, Daoism seeks to guide its believers beyond this transitory life to a happy eternity. Daoists believe in an original state of bliss, which is followed by the present human condition, the fallen state. Daoists also rely on supernatural powers for help and protection.

Daoists believe in a supreme emperor deity called Yu-huang-da-di, who governs over a heavenly universe of deities and immortals, many of them famous historical figures. The Daoist religion offers its doctrines of the cosmos and the cosmic process and harmony, tracing all back to the great ultimate (*tai chi*) and to the interactions of the two great modes of *yin* and *yang*. Yin, the great feminine mode, denotes all figures, things, and processes of negativity, passivity, staticity, and concealment. Yang, the great masculine mode, denotes all figures, things, and processes of positivity, activity, dynamism, and manifestation. Yin and yang are the basic principles for classification and explanation in traditional Chinese daily life, science and technology, medicine, and philosophy. With such unique categories, a truly traditional "Chinese science" is very different in character from a Westernized scientific enterprise in modern China.

Daoists do not conceive of eternal life in terms of spiritual immortality alone. They anticipate the survival of the whole person, including the body. The means by which Daoism pursues immortality, which should enable immortality to be realized in this life on Earth, are empirical and congenial to the geographical environment, to health care, and to elixir alchemy. Thus, the influence of Daoism on the development of traditional "Chinese science" is substantial.

Mohism

In Chinese, a follower of Confucianism is called a *ru*. The *ru* and the *hsieh* (knights errant) originated as specialists attached to the houses of the aristocrats and were themselves members of the upper classes. In later times the *ru* continued to come mainly from the upper or middle classes, but the *hsieh* were more frequently recruited from the lower classes. In ancient times, such social amenities as rituals and music were exclusively for aristocrats; for the common person, therefore, rituals and music were luxuries that had no practical utility. It was from this vantage point that Mo Zi and the Mohists, who came from the *hsieh* class, criticized the traditional institutions, including Confucius and Confucianism.

Unlike Confucius, Mo Zi believed in a personal God and the existence of spirits, and he submitted himself to the will of God. He saw his mission as rescuing the people from suffering, and he proclaims the all-embracing love. He and his followers explored science and technology so they would have the skills they needed to put their ideas into practice.

The school of Mohism introduced epistemology, as well as formal, abstract, and geometrical notions such as a dimensionless geometrical point in space and time. According to Mohist epistemology, the knowing faculty must be confronted with an object of knowledge. The human mind interprets the impressions of external objects, which are brought to it by the senses. The *Mo Jing* (Book of Mohism) provides various logical classifications of knowledge. For example, names are classified into three kinds: general, classifying, and private. The knowledge of correspondence is that which knows which name corresponds to which actuality. Such knowledge is required for the statement of a proposition like "This is a table." When one has this kind of knowledge, one knows that "names and actualities pair with each other" (*Mo Jing,* Ch. 42).

Mohists also touch on atomic theory in their discussion of the strengths of materials, but they never articulate it clearly or develop its consequences. The *Mo Jing* also contains some remarkable statements about the study of motion. Though ancient Chinese scientists accomplished little in theoretical dynamics, they did consider forces in some detail, and they appear to have come remarkably close to the principle of inertia as stated by Isaac Newton (1642–1727). Mohists also investigated the relativity of motion, motion along inclined planes or slopes, and particular problems of moving spheres. Unfortunately, Mohism disappeared during the first century B.C.E., and its important scientific findings were only rediscovered in the twentieth century.

Cosmology

During the first century B.C.E., an impressive cosmology arose in China. "Before heaven and earth had taken form all was vague and amorphous. Therefore it was called the Great Beginning. The Great Beginning produced emptiness, and emptiness produced the universe. The universe produced material-force, which had limits. That which was clear and light drifted up to become heaven, while that which was heavy and turbid solidified to become earth" (*Huai-nan Tzu* 3:1a). This cosmology is different from that of Buddhism, for Buddhists maintain that the origin of the universe comes from the blind consciousness that is no reality. Daoism, however, maintains that the origin of the universe lies with the great ultimate (tai chi), which is also called *wu* (literally, nothingness or nonbeing). The tai chi emblem, which consists of a circle with an s-shaped curve dividing it into two complementing black and white regions, represents respectively the yin and yang as two great modal forces of the cosmos in mutual interpenetration. Each region being punctured in the middle by a dot of the opposite region, further underscoring this dialectical interpenetration. It is meant to be an empirical sign of the origin of the universe.

The cosmology of Confucianism is explained by the *Tai-chi-t'u-shuo* (An explanation of the diagram of the Great Ultimate) by Chou Tun-i, a scholar who lived during the Sung (Song) dynasty (960–1297 C.E.) and a pioneer of neo-Confucianism. Although Chou Tun-i may have obtained his diagram from a Daoist priest, it is unlike any diagram of the Daoists. For Chou Tun-i, the great ultimate is an abstract principle that is the ultimate metaphysical reality. In his explanation, the myriad things are created through the evolutionary process of creation from the great ultimate through the dialectical interaction of the passive cosmic force, yin, and the active cosmic force, yang. Chou Tun-i faithfully followed the *Book of Changes* or *I-ching* rather than Daoism. He assimilated the Daoist concept of nonbeing with Confucian thought, but in so doing he discarded the fantasy and mysticism of Daoism. This diagram of Chou Tun-i has been described as a cosmology of creation without a creator.

In his diagram he said that the ultimate of nonbeing is also the great ultimate (tai chi). The great ultimate generates yang through movement. When its activity reaches its limit, movement turns into tranquility. The great ultimate generates yin through tranquility. When tranquility reaches its limit, activity begins again. So movement and tranquility alternate and become the cause of each other, giving rise to the distinction of yin and yang, and the two modes are thus established. By the transformation of yang and its union with yin, the five agents, elements, or phases of metal, wood, water, fire, and Earth arise. When the material forces of these five agents are distributed in harmonious order, the four seasons run their course. The creating order is called Dao (the Way), which governs not only the Earth but also human life and society. Following the Dao should be the purpose of all one's activities, including governmental, societal, familial, and personal ones. Thus, Dao as the most fundamental principle or cosmological law is objective and natural.

Other sciences in Chinese history

Astronomy. There was no distinction between astronomy and astrology in traditional China. The oracle bone inscriptions include records of eclipses, novae, and names of stars and some constellations, and star catalogs were produced during the Warring States period. The earliest extant Chinese documents on astronomy are two silk scrolls discovered in 1973 in the Mawangdui tombs in Changsha in the Hunan province. One of them, the *Wuxingzhan* (Astrology of the five planets), which was written between 246 and 177 B.C.E, contains records of Jupiter, Saturn, and Venus, the accuracy of which suggests the use of an armillary sphere for measurement. An important role of Chinese astronomy was calendar calculation. Every emperor regarded calendar making as one of his duties associated with the mandate that he received from heaven. The calendar, issued in the emperor's name, became part of the ritual paraphernalia that demonstrated his dynastic right to rule. Astrological observations could easily be manipulated and thus could be dangerous in the hands of someone trying to undermine the current dynasty. It was therefore a principle of state policy that the proper place to conduct astronomical studies was the imperial court. During certain periods it was illegal to do it elsewhere. Thus, an ancient scientific pursuit such as astronomy was deeply embedded in the social matrix of ancient China, although Chinese astronomy could not be pursued as an independent activity like its modern western counterpart.

Medicine. Classical Chinese medicine has often been represented as an empirical science that is based on the clinically sound use of effective natural drugs and other remedies. Scientific theories served primarily as mnemonic devices or as mystification to confuse the untrained. Some scholars portray classical Chinese medicine as a corpus of theory-based adaptations of the yin-yang and five-agents concepts. As such, the body was understood as a multilevel interconnected system, and illnesses were treated holistically. The most famous medical texts were compiled before the Qin period (before 211 B.C.E.) and completed during the Han dynasty. Among extant texts, the most important are *Huangdi Neijing* (Yellow Emperor's inner canon) and *Shennong Bencao Jing* (Divine husbandry's classic of herbology), which laid the foundation for clinical science with definite treatment and diagnostic principles. Chinese pharmacology also reveals outstanding achievements during this period. Shennong's *Classic of Herbology* presents many effective remedies. It also provides the theoretical basis of drug use, as well as the collection, preservation, and mixing of herbs, and their methods of administration.

From the second century C.E. onward, medical disciplines were professionalized. Clinical medicine developed greatly from the third to the tenth centuries. The *Zouhou Beiji Fang* (Handbook of prescription for emergency) in the fourth century includes information on smallpox and a treatment for hydrophobia that used the brain tissue of a mad dog. The academic standard of Chinese medicine was further upgraded during the Ming and Qing dynasties (1368–1911 C.E.). A new medical school was established to study acute infections, and researchers there successfully tackled many infectious diseases, including B-encephalitis, acute viral hepatitis, and other viral diseases.

Chinese medicine never produced a detailed and accurate picture of anatomy and physiology. The philosophical concept of yin-yang was the basic theory for interpreting complex relationships between the upper and lower emotions, the inner basis and the outer manifestations of the body's activities and functions. Moreover, classical Chinese medicine was not concerned with microorganisms or details of the body's organs and tissues. The strength of classical Chinese medical discourse lies rather in its sophisticated analysis of how bodily functions are related on many levels, from the vital processes of the body to the emotions, to the natural and social environment of the patient. In this sense, traditional Chinese medicine stresses a holistic view of health rather than analytical research on the physical body.

See also CHINESE RELIGIONS AND SCIENCE; CHINESE RELIGIONS, CONFUCIANISM AND SCIENCE IN CHINA; CHINESE RELIGIONS, DAOISM AND SCIENCE IN CHINA

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HING KAU YEUNG

CHRISTIANITY

Christians were first called "Christians," according to Acts 11: 26, at Antioch in 40 to 44 C.E. A Christian is one who accepts Jesus of Nazareth as Messiah (or in Greek, the Christ), the Anointed One of God—the one who shows and makes present in history God's nature and purpose for creation.

Normally Christians believe in one creator God, threefold in being (Father, Son, and Spirit). The Son is the Logos or Wisdom of God, the archetype of all creation, who was incarnate in Jesus, reconciling an estranged creation to the divine being through Jesus' death and resurrection. The Spirit, the creative energy of God, is known in the fellowship of the Church, which mediates the presence of the risen Christ to the world. Christians believe that human beings have turned away from the love of God to selfish desire (are "in sin"), but God wills that all should turn back to God, and in Christ calls them and empowers them to return. At the end of history, Christ will be disclosed in glory, and all who have not finally rejected God will receive the gift of eternal life in the presence of God. The "gospel," or good news, is that God forgives sin and offers eternal life to all through Christ.

Christianity has expanded from a small Jewish messianic sect to become the largest religion in the world, with an estimated two billion adherents. It has taken many forms, and there are well over a thousand Christian denominations. Some denominations think of themselves as "Biblical Christians," meaning that they take the Bible as the basis of faith, and often interpret the historical records, including accounts of miracles and of the coming end of the world, as literally as possible. Such groups sometimes find themselves in conflict with the claims of science, most obviously over the age of the universe, the origin of human life, and the probable end of the world.

The mainstream denominations—especially Roman Catholic, Reformed, Lutheran and Anglican—are not committed to biblical literalism. It has become standard to interpret the Genesis accounts and teachings about the end of the world as myths, the purpose of which is to teach the dependence of all things on God, and the final destiny of the universe as lying in union with (or final separation from) God. More radical movements seek to reconstruct Christian faith in terms of personal commitment to agapistic love (to the kingdom of God, seen as a moral community), or of apprehension of the Transcendent, as it is disclosed in Jesus. Nevertheless, belief in God as creator is usually affirmed, and Jesus is seen as a unique instance of God's action in the world, from whose life, death, and resurrection the church originates, as the way of reconciling the world to God. The experimental sciences have flourished in this intellectual environment, since it affirms the rational intelligibility of the universe, as created by a wise God, and gives humans the responsibility for having "dominion" over, or care for, the creation.

See also CHRISTIANITY, ANGLICAN, ISSUES IN SCIENCE AND RELIGION; CHRISTIANITY, EVANGELICAL, ISSUES IN SCIENCE AND RELIGION; CHRISTIANITY, LUTHERAN, ISSUES IN SCIENCE AND RELIGION; CHRISTIANITY, ORTHODOX, ISSUES IN SCIENCE AND RELIGION; CHRISTIANITY, PENTECOSTALISM, ISUSES IN SCIENCE AND RELIGION; CHRISTIANITY, RADICAL REFORMED, ISSUES IN SCIENCE AND RELIGION; CHRISTIANITY, REFORMED, ISSUES IN SCIENCE AND RELIGION; CHRISTIANITY, ROMAN CATHOLIC, ISSUES IN SCIENCE AND RELIGION; SCIENCE AND RELIGION, HISTORY OF FIELD

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KEITH WARD

CHRISTIANITY, ANGLICAN, ISSUES IN SCIENCE AND RELIGION

The initial impulse given to Anglican thought in the sixteenth century was a confident belief in God as creator of the world, which, though fallen, was intelligible to human understanding. From biblical, patristic, and medieval sources, Anglican liturgy gave expression to the praise of God, notably in the daily use of the book of Psalms, and of canticles such as the *Benedicite* and *Te Deum.* Although initially the reformed Church of England understood itself as a form of Protestantism, the vision of balancing God's work in creation and in human history was somewhat distinctive, giving its thought a somewhat less anthropocentric character.

Views of nature

This positive perspective on nature comes to expression in the classic theology of Richard Hooker (1554–1600). Within a generally hierarchical and Aristotelian view of nature, Hooker insists on God's work as artist, guide, and providential director within nature. Its constancy and dependability are the source of human knowledge of its laws. Natural objects are moved by God as instruments of his being. The same theme is also evident in the poetry of George Herbert (1593–1633), who assigns to humanity the role of being secretary to the praise offered by the whole of creation. A very powerful and individual voice is that of the Anglican poet Thomas Traherne (1636–1674), who takes a mystical delight in the beauty of the created order.

Interaction with the sciences

Certain specific conditions made England a particularly hospitable place for the burgeoning of natural theology after the condemnation of Galileo Galilei (1564–1642) in 1616 and 1633. The founding of the Royal Society of London for the Improvement of Natural Knowledge (known as the Royal Society) in 1660 benefited both from the comparatively loose structure of authority in the Church of England and from a certain degree of toleration of diversity of opinion. In fact, Thomas Sprat (1635–1713), the first writer of the history of the Royal Society, wrote, "The Church of England therefore may justly be styl'd the Mother of this sort of Knowledge; and so the care of its nourishment and prosperity peculiarly lyes upon it" (quoted in Peacocke, p. 5).

Isaac Newton (1643–1727) was an Anglican reared in the scholasticism of Cambridge, but open to the new influences from mechanical philosophy. In his *Opticks* (1706) Newton assigned to God the duties of preventing the stars from collapsing together and of reforming the mechanism of the world to prevent it from subversion by irregularities. The rationalism of this scheme was complemented by his approach to Scripture, which he denied taught the doctrine of the Trinity. But it is clear that Newton was by intention a pious believer and theological thinker as well as a brilliant scientist.

The same atmosphere of toleration supported the scientific work of non-Anglican Protestants, notable among whom was the naturalist and theologian, John Ray (1627–1705). A fellow of the Royal Society, Ray's exceptional work of taxonomy was carried outside the Anglican universities, and his late work, *The Wisdom of God Manifested in the Works of the Creation* (1691), advanced the argument from design influential throughout the coming century.

Although mechanistic philosophy was strongly attacked by many Anglican theological writers (and poets) of the eighteenth century, the teleological argument for the existence of God remained popular, receiving influential expression in the work of the philosopher William Paley (1743–1805), an Anglican priest, and author of a standard textbook, *Natural History* (1802). This book was studied by Charles Darwin (1809–1882) as a student, and its arguments are still worthy of consideration.

An attempt to find a version of the mechanical philosophy compatible with theism was a feature of the Cambridge scientist, ethicist, and theologian, William Whewell (1794–1866). An ordained Anglican as well as a founding member and early president of the British Association for the Advancement of Science and a Fellow of the Royal Society, Whewell stressed the inductive and historical character of science. At the same time he held that God's creation of the world guaranteed the simplicity and comprehensibility of the laws governing nature.

Darwin's own discoveries and writings provided, and still provide, an enormous stimulus to Anglican, as well as to all English-language theology. The dominant idealism of late nineteenth-century English universities had little difficulty in adapting to the implications of Darwinian thought, and Darwin himself was buried, without controversy, in Westminster Abbey.

The dialogue since Darwin

After Darwin and the opening of Oxford and Cambridge to non-Anglicans, it became more difficult to identify a specifically Anglican strand in the generally vibrant relations of science and theology. After the second world war, however, a further burgeoning took place in Anglican responses to scientific developments. In 1942 an Anglican theologian, Charles E. Raven (1885–1964), produced a major biographical study of John Ray, following it later with a two-volume history of religion and science (*Natural Religion and Christian Theology,* 1953).

From the 1970s two authors, both Anglican priests, biologist Arthur Peacocke (1924–) and physicist John Polkinghorne (1930–) have made major contributions. For Peacocke the theological interpretation of how God is related to the world must be rethought in the direction of panentheism, God suffering in and with the world processes. For Polkinghorne, God is active within the world, though in a self-limited, kenotic way.

Attempts to popularize the discoveries of science have led to a continuing public interest and debate, especially on the ethical problems of gene technology. Notable contributions have been made by an Anglican bishop and geneticist, John Habgood (1927–), Archbishop of York from 1983 to 1995.

See also DARWIN, CHARLES; NATURAL THEOLOGY; NEWTON, ISAAC; PANENTHEISM

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STEPHEN SYKES

CHRISTIANITY, EVANGELICAL, ISSUES IN SCIENCE AND RELIGION

The term *evangelical* (from the Greek word for gospel) has several meanings; for the purpose of this entry, it will refer to an English-speaking Protestant development that emphasizes personal religion (focused on Christ), Biblical authority and preaching, missions, and evangelism. The origins of this particular type of evangelical Christianity stretch back to eighteenth-century revivals in England and America, with such leading figures as John and Charles Wesley, Jonathan Edwards, and George Whitefield. Early evangelical leaders and scholars accepted a harmony between natural science and religious faith, typical of the age of British natural theology. Edwards saw the glory of God revealed in a spider's web, while Wesley could find the wisdom of God revealed in creation as understood by the natural science of his day. For the most part, evangelical scientists and theologians sought a harmony between science and Scripture.

Views of nature

Evangelicals understand the natural world in terms of Biblical theism and the doctrine of creation. God is the author of nature and of the contingent order of the natural world. Nature was created good, and exists for the purpose of glorifying God. Sin, however, has distorted and warped nature, especially human nature. God will eventually redeem nature and all things through Christ. Thus the natural world serves as a stage for the great drama of salvation: sin and corruption, salvation and redemption. Because it is subject to a higher, spiritual order, evangelicals believe that the stability of natural law may be altered for a higher purpose, without undermining the reliability of natural science. They defend both the value of natural science and the stability of natural law, along with the reality of miracles in the context of God's plan for nature and history.

Interaction with the sciences

With a few exceptions, the general picture of harmony between faith and science did not change in any marked degree after the publication of Charles Darwin's *Origin of Species* in 1859. Given the vitriolic rejection of Darwinism by populist evangelicals in the early twentieth century, this may seem unlikely; but the fact is that most evangelical scholars and natural scientists before World War I accepted some form of evolution, even if some were attracted to non-Darwinian variations, such as that of Jean Baptiste Lamarck. They rejected "Darwinism" when that term was identified with atheism or naturalism (e.g., the Princeton theologian Charles Hodge). Prominent evangelical theologians and scientists of the late nineteenth century, such as James Orr, B. B. Warfield, and A. H. Strong (theologians), or James D. Dana, David Brewster, and Asa Gray (scientists), could all advocate a combination of biological evolution and Biblical religion. There were, of course, critics of evolution among evangelicals in this period, but that was not the dominant mood. The scientific and religious critics of Darwin in the nineteenth century came from a great variety of religious perspectives, and cannot be typified as predominantly evangelical.

After the first World War, the cultural mood changed in the West, and among evangelicals. The horrors of war stimulated a more world-denying, counter-cultural popular religion. Pre-millennial eschatology became popular in the new movement, soon called "fundamentalism." This eschatology expected the imminent return of Jesus and the decline of worldly culture until his return. In this populist movement, evolution was associated with progress, with liberalism, and even with biblical criticism. Because the Book of Revelation was read in a literal way, so was Genesis. Evolution and Darwin were rejected in favor of biblical literalism and tribulation preaching in which the "tribulation" is the period of woes and sufferings predicted in Revelation. The main spokespersons for this populist pre-millennial movement were not scholars and scientists but preachers and pamphleteers. This is the reason the famous Scopes trial in Dayton, Tennessee, took place in 1925 after the rise of fundamentalism, and not earlier. The anti-evolutionary forces in Dayton were lead by the populist politician William Jennings Bryan, not by scholars. It is no accident that the first major "creation scientists" was an Adventist (George McCready Price) because of the close association of populist pre-millennial eschatology and anti-evolutionary rhetoric in American church history. The rise of this kind of fundamentalism also marked the end of the harmony between natural science and biblical religion as a predominant mood within evangelicalism.

The so-called creation science movement was an attempt to give this anti-evolutionary point of view some scientific respectability. Henry Morris was particularly influential, but few serious biologists joined this association. Despite the work of the Institute for Creation Research in Santee, California, and other loose associations of creationists, creation science has remained a populist movement with little scientific respectability. It thrives predominantly within pre-millennial movements, rather than among associations of scientists and scholars. Like earlier fundamentalists, they are often accused of relying upon popular politics, rather than scientific literature, to oppose evolution.

The dialogue since World War II

After the Second World War, some conservative scholars and church leaders saw a need to engage with culture, including science. Carl Henry, Bernard Ramm, and E. J. Carnell, along with English evangelicals like John Stott, were among the theologians who advocated a rejection of fundamentalism and a return to social engagement and scholarly achievements. In his influential book *A Christian View of Science and Scripture* (1954), Ramm reasserted the older evangelical harmony between science, including evolution, and the Bible. Associations of evangelicals who were also scientists, such as the American Scientific Affiliation (ASA) and the Victoria Institute in England, help promote this reengagement. In 1959, members of the ASA, a group previously noted for its anti-evolutionary stance, published Russell Mixter's *Evolution and Christian Thought Today,* a controversial work cautiously in favor of scientific evolution.

Given this complex history, evangelical scholars and scientists remain conflicted with respect to evolution. Unlike their fundamentalist ancestors, evangelicals embrace natural science and scholarship in general. The majority of evangelical scholars would advocate a Christian approach to the sciences that unites faith and reason, rather than the anti-intellectual rhetoric of the fundamentalist movement. But with respect to evolution, some evangelicals remain dubious. In particular, the Intelligent Design movement (popular among evangelicals) includes scientists, philosophers, and theologians who argue that life on Earth is the result of intelligent design. They seek to reject Darwinism, as they understand it, while still accepting natural science as a whole. On the other hand, many evangelical systematic theologians like Thomas F. Torrance are willing to accept biological evolution, while still holding that the universe is created, sustained, and ordered by God.

See also CREATIONISM; DARWIN, CHARLES; DESIGN; INTELLIGENT DESIGN; SCIENCE AND RELIGION, MODELS AND RELATIONS

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ALAN G. PADGETT

CHRISTIANITY, HISTORY OF SCIENCE AND RELIGION

The fundamental question facing the Christian scholar in any discipline can be seen as a specific form of a general query that was posed within two centuries of Christ's death by the Carthaginian father Tertullian (c. 155–230): "What indeed has Athens to do with Jerusalem? What concord is there between the Academy and the Church?"

Before the Renaissance

As the phrasing implies, Tertullian's attitude toward Greek philosophy was generally negative, though he acknowledged a legitimate role for reason within the bounds of religion. Other patristic authors looked more favorably on pagan philosophy and literature, especially Origen (c. 185–254), who required his students to read nearly every work available to them at the time and found some truth in most of them. The moderate position of Augustine of Hippo (354–430), who considered reason a divine gift resting on the foundation of faith, was by far the most influential on later Christian thinking. Although he cautioned Christians not to devote too much energy to the study of nature, which cannot lead to salvation, Augustine recognized Greek scientists as reliable authorities on natural matters and cautioned Christians against making nonsensical claims about nature, based on some presumed meaning of scripture, for this would only cause people to laugh at the ignorance of Christians. He also urged believers to study nature, "the great book . . . of created things."

Most patristic writers recognized two valid sources of knowledge—scripture and reason, including most conclusions of reason about nature—but assigned a different status to each. Prior to the Renaissance, philosophy (including what is today called science) was considered a "handmaiden to theology," while theology was "queen of the sciences," where "science" meant knowledge in general and not simply knowledge of nature. This terminology was introduced by the Hellenistic Jewish scholar Philo of Alexandria (30 B.C.E.–50 C.E.) and later was used by Christian writers such as Clement of Alexandria (c. 150–215), Augustine, and Bonaventure (1221–1274). On this view, the proper role of scientific knowledge was to help illuminate biblical references to nature, not to stand on its own as an independent domain of inquiry. This is clearly seen in the numerous commentaries on the six days of creation from this period, such as the *Homilies on the Hexameron* by Basil, Bishop of Caesarea (c. 330–379), in which Aristotelian cosmology and physics were used to help interpret references to the heavens in the first chapter of Genesis.

For nearly twelve hundred years the handmaiden model escaped serious challenge, mainly because copies of most Greek scientific and medical texts were unavailable in northern and western Europe, and what little knowledge Christian scholars did have of such texts was usually obtained indirectly, from handbooks and encyclopedias rather than from the original sources. Consequently, Christian scholars were not confronted with the full force of Aristotle's sophisticated naturalism. On the other hand, they did have Plato's *Timaeus,* a dialogue about creation in which a god imposes mathematical form on undifferentiated matter. Although the differences between Plato's story and Genesis are significant, there are enough similarities that Plato was readily seen as a pagan prophet of Christianity. Plato's rejection of purely natural and unintelligent causes in forming the world, coupled with his belief in the immortality of the soul and the superiority of mind over matter, made him highly attractive to Christian writers. The relative ease with which Platonic elements could be incorporated into a Christian world view—and vice versa, depending on who was doing the philosophizing—gave considerable support to the handmaiden model.

The situation changed dramatically with the reintroduction into northern and western Europe of a large body of Greek scientific and medical works. This process began around 1000 C.E. and led within two centuries to the appearance of universities dominated by Aristotelian natural philosophy, strongly flavored by the ideas of Islamic scholars who had worked with translations of Greek texts for hundreds of years. The influence of Ibn Rushd (known in the West as Averroës, 1126–1198), an extreme rationalist who elevated Aristotle over traditional Islamic teaching, was especially important in this connection. Christian scholars were now faced with a powerful, systematic body of natural knowledge, comprehensive in scope and secular in spirit, and they responded in various ways.

At the University of Paris, the leading theological faculty in Christendom, led by the conservative Bonaventure, grew alarmed at certain teachings promulgated by some masters on the faculty of arts, especially Siger of Brabant, a radical Aristotelian who considered philosophy to be an autonomous discipline, perhaps even superior to theology. Several times in the thirteenth century, Aristotle's books were banned at Paris, culminating in 1277 when the bishop of Paris, Étienne Tempier, condemned 219 specific propositions as heretical. These included several ideas associated with Thomas Aquinas (c. 1225–1274), a moderate Dominican who had taught theology at Paris and had carefully integrated Aristotle with Christian theology. Ironically, Aquinas was canonized in 1323 and his ideas later became the basis for one of the leading Christian systems of thought, Thomism. A further irony is that the condemnation inspired the important Parisian natural philosophers John Buridan (c. 1295–1358) and Nicole Oresme (c. 1320–1382) to consider what a non-Aristotelian science of motion might be like, including the possibility of a rotating Earth. Although their ideas probably did not lead directly to the scientific revolution (as Pierre Duhem and some others have claimed), they do show that theology can stimulate significant scientific insights.

Renaissance to mid-nineteenth century

In the later middle ages and continuing into the Renaissance, partly in reaction to the hold Aristotelianism had gained on the universities, Platonism enjoyed a revival. Many Renaissance thinkers followed Plato by emphasizing mathematics as the key to understanding nature, but differed fundamentally from Plato in their belief that the physical world perfectly embodies God's geometrical design; Plato had taught that physical objects are only imperfect "shadows" of the perfect forms. The difference was a consequence of the Christian doctrine of creation: An omnipotent God would carry out the plan of creation to perfection. For Christian neo-Platonists like Nicolas Copernicus (1473–1543), Galileo Galilei (1564–1642), and Johannes Kepler (1571–1630), God was eternally thinking geometric thoughts. By the right use of geometry, one might literally read the mind of God and discover the deepest secrets of creation. Inspired partly by his neo-Platonist beliefs and strongly encouraged by church authorities to publish his ideas, the quiet and conservative Copernicus advanced a radical new theory of the universe that placed the Earth in motion about a stationary sun. Kepler found this theory attractive for several reasons, including his belief that the three parts of the Copernican universe symbolized the Trinity—the central sun with its emanating light representing God the Father, the starry sphere God the Son, and the intermediate space God the Holy Spirit.

There was no convincing proof for the new astronomy, however, and many scientists and theologians alike saw the hypothesis of the Earth's motion as a challenge to those biblical passages (about a dozen in all) that seemed to speak either of the motion of the sun through the sky, as if it were a real motion rather than an apparent one, or else of the stability of the Earth. In defense of the new astronomy, Kepler (a German Protestant) and Galileo (an Italian Catholic) both employed the Augustinian principle of accommodation to justify the figurative interpretation of biblical references to the motion of the sun. The Bible, they argued, speaks in a human way about ordinary matters in a way that can be understood by the common person, using ordinary speech to convey loftier theological truths. Thus, the literal sense of texts making reference to nature should not be mistaken for accurate scientific statements, but the wise interpreter could show how the book of scripture did not really contradict the book of nature. Citing rules established by the Council of Trent in response to Protestant reformers, Catholic authorities found this unacceptable and ordered Galileo not to teach the new astronomy. Galileo, who often treated opponents arrogantly, ignored this warning and published a vigorous attack on traditional astronomy in which he thoughtlessly insulted his friend, Pope Urban VIII, and Galileo was sentenced to house arrest by the Inquisition in 1633.

Those Christian thinkers who agreed with Kepler and Galileo—and by 1700 a large number did—were implicitly raising the status of science from that of an obedient handmaiden to something like an equal partner in the search for truth—a conception that had been explicitly endorsed just a few years earlier by the English statesman and essayist, Francis Bacon (1561–1626), who was ironically not a Copernican himself. Bacon held that nature served as a "key" to the scriptures, not only by "opening our understanding to conceive the true sense of the scriptures," but mainly by "opening our belief, in drawing us into a due meditation of the omnipotency of God, which is chiefly signed and engraven upon his works." At the same time, however, he cautioned against "unwisely confounding these learnings together."

Because it offered relative autonomy for science while enhancing the authority of theology, the Baconian attitude was widely adopted by Protestants in England and America through the middle of the nineteenth century, and Roman Catholics were increasingly attracted to a similar attitude, partly seen in Galileo but ultimately derived from Aquinas. English natural philosopher Robert Boyle (1627–1691) epitomized this approach, promoting what he called the "mechanical philosophy"—the explanation of natural phenomena in terms of matter and motion—over Aristotelian and Galenic views, for its advantages not only to science (it provided clear, experimentally useful explanations) but also to religion: By denying any immanent intelligence to "Nature," which functioned idolatrously as a "semi-deity," the mechanical philosophy more clearly distinguished the creator from the creation, thus focusing worship where it properly belonged. Boyle further believed that Christian character was highly relevant to the scientific enterprise, such that he considered himself a "priest of nature" whose discoveries only enhanced his appreciation for the wisdom, goodness, and power of God. Like many of his contemporaries, including Isaac Newton (1642–1727), Boyle aggressively pursued an extensive program of natural theology while generally avoiding the use of the Bible as a scientific text.

More than a century later, however, Christian thinkers were much less reluctant to cite scripture on scientific matters, no doubt because the age and origin of the Earth had become topics of serious scientific discussion. Many natural historians and theologians saw in the books of nature and scripture essentially the same story, going beyond the general assumption of harmony to endorse a strong concordism, arguing for close parallels between Genesis and geology and sometimes inventing elaborate hermeneutical schemes to achieve harmonization.

Since the mid-nineteenth century

With the acceptance of Darwinian evolution, however, concordism fell out of favor, though some conservative Protestants still embrace it, and no single approach to theology and science has generated a wide enough following to function as its replacement. The first American Darwinian, botanist Asa Gray (1810–1888), thought that his acceptance of evolution had no bearing on his belief in the miracles of Christ and the doctrines affirmed by the Nicene Creed, thus holding a compatibilist or complementarian view of theology and science. At the same time, Gray tried to rebuild natural theology along evolutionary lines—a combination that has never been common, although a number of orthodox and neo-orthodox thinkers in the following century held some type of complementarian position.

From the 1870s to the 1920s, many Protestant scientists and theologians and some Roman Catholics believed that higher biblical criticism, as well as natural science, mandated the formulation of a new theology stressing divine immanence, God's everyday working in and through the processes of nature. Some liberals took this further, including several modernists from the 1920s who denied miracles and special revelation and essentially identified God with the laws of nature, thus completely rejecting divine transcendence. Liberals saw morality as the essence of religion; asserting the fundamental goodness and perfectibility of humanity, many also believed that the science of eugenics would help them establish the kingdom of God on Earth. Both world wars had a devastating impact on such an optimistic view, leading Karl Barth (1886–1968) and other neo-orthodox theologians to reassert sin, revelation, and divine transcendence. Because he understood God as wholly other, and also because he deplored the ways in which the German churches had capitulated to the state, Barth denied that one can learn about God apart from revelation, thereby completely rejecting natural theology.

Around the same time, the English logician Alfred North Whitehead (1861–1947) argued that the very possibility of modern science depended upon the unconsciously held belief, derived from medieval theology, that the created order must be intelligible, thus finding an inextricable link between theology and science. He also developed a highly sophisticated process metaphysics that has profoundly influenced some important modern theologians, philosophers, and scientists. Motivated partly by a desire to embrace evolution and even more by a desire to mitigate God's responsibility for suffering, process theologians believe that God has only limited power to influence natural and human events, rather than the omnipotence needed to create the world *ex nihilo.* The world and God are seen as coeval entities evolving together, and many contemporary process thinkers follow Charles Hartshorne (1897–2000) in affirming panentheism rather than traditional theism. Ironically, perhaps the greatest challenge to process theology comes from the modern science it seeks to embrace, but from the evolution of the cosmos rather than the evolution of life. Since the mid-1960s, astronomers have discovered a wealth of evidence favoring the Big Bang theory of cosmology, evidence suggesting not only that the universe had a "beginning" but also that the laws of nature were exquisitely tuned for the presence of living things. Many think that a universe with these features seems more consistent with *creatio ex nihilo* than its denial.

At the dawn of the twenty-first century, a good number of leading Christian scientists and theologians, including some who combine that role, such as Ian Barbour (1923–), Arthur Peacocke (1924–), and John Polkinghorne (1930–), are engaged in a growing international conversation about issues of interest to both communities, and the range of opinion reflects disagreements about the nature of God, the nature of humanity, and the nature of nature.

See also CHRISTIANITY, ANGLICAN, ISSUES IN SCIENCE AND RELIGION; CHRISTIANITY, EVANGELICAL, ISSUES IN SCIENCE AND RELIGION; CHRISTIANITY, LUTHERAN, ISSUES IN SCIENCE AND RELIGION; CHRISTIANITY, ORTHODOX, ISSUES IN SCIENCE AND RELIGION; CHRISTIANITY, PENTECOSTALISM, ISSUES IN SCIENCE AND RELIGION; CHRISTIANITY, RADICAL REFORMED, ISSUES IN SCIENCE AND RELIGION; CHRISTIANITY, REFORMED, ISSUES IN SCIENCE AND RELIGION; CHRISTIANITY, ROMAN CATHOLIC, ISSUES IN SCIENCE AND RELIGION; SCIENCE AND RELIGION, HISTORY OF FIELD

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EDWARD B. DAVIS

CHRISTIANITY, LUTHERAN, ISSUES IN SCIENCE AND RELIGION

When Martin Luther (1483–1546) in 1517 publicly attacked the notion of merit and grace in scholastic theology, denounced the church practices of penance and indulgence, and soon after opposed the authority of the Pope, he inadvertently triggered a long-term schism between Catholics and Protestants within the Western church. All reformation movements of the sixteenth century are indebted to Luther's notion of unconditional grace, but the movements developed differently. Already in 1524 Luther fiercely opposed the Radical Reformed movement of Thomas Müntzer (1490–1525) and others, and from 1526 to 1528 Luther took issue with the interpretation of the Eucharist among the Swiss reformers. Consequently, relatively few countries in Northern Europe (notably Germany and the Nordic countries) defined themselves as "Lutheran," whereas the Swiss, Dutch, and English reformations were eventually more influenced by John Calvin (1509–1564) than by Luther. In the nineteenth century, new Lutheran emigration churches were formed in the United States, Brazil, and Argentina. During the twentieth century major indigenous Lutheran churches emerged in Africa, especially in Tanzania, Madagascar, and Namibia, and in Asia, especially in India and Indonesia.

Views of nature

In his early career, Luther's view of nature was framed by the contrast between divine grace and human nature. In the *Heidelberg Disputation* (1518) Luther renounced natural theology as a "theology of glory" that vainly sought to identify God in the niceties of life. Not nature, but the cross of Christ is the gateway to God. The target of this critique, however, was not nature but self-centered trust in the capacities of human reasoning in grasping God. Luther regarded life as a divine gift, and according to *Small Catechism* (1529) the human body and soul as well as nature and society are created and preserved by God "out of pure fatherly, and divine goodness and mercy, without any merit or worthiness of mine at all." Luther was not so much interested in "pure nature" as in the manner in which nature and culture interweave in ordinary life: "Our house, home, field, garden and everything is full of the Bible, because God through his wonderful work knocks on our eyes, touches our senses and shines right into our hearts." Thus, even if Luther rejected the pursuit of natural theology, he articulated a rich theology of nature from the existential perspective of faith.

Luther's positive view of nature came to the fore in his controversy with Huldreich Zwingli

(1484–1531) on the Eucharist. Luther insisted on a literal understanding of the words of Jesus Christ: "This is my body." God is not only present in creation as Spirit, but through Christ God is ubiquitous in the midst of the material world, in the natural elements of bread and wine. The Medieval distinction between the natural and the supernatural thus became obsolete, and Luther criticized the Roman Catholic doctrine of *transubstantiation* accordingly. Natural bread and wine are not changed (substantiated) into the supernatural body and blood of Christ. Rather, Christ is present "in, with, and under" natural bread and wine. In later Lutheranism, this idea of *consubstantialization* was developed into a more general principle of *finitum capax infiniti* (the finite is capable of embodying the infinite). In this vein, seventeenth-century Lutheran Orthodoxy developed a theological materialism in contrast to the more spiritual ontologies of Zwingli and Calvin. In the twentieth century, these ideas also influenced the sacramental realism of Anglican theologians such as William Temple (1881–1944) and Arthur R. Peacocke (1924–).

Interaction with the sciences

Luther did not himself show any interest in natural science; he preferred to stay within the Biblical worldview. But Luther's close collaborator Philip Melanchthon (1497–1560), who was in charge of the university reform in Wittenberg, strongly supported natural philosophy, as the sciences were called at that time. In his textbook *The Elements of Natural Philosophy* (1549) Melanchthon taught that the entire physical cosmos manifests God's providential order. Melanchthon also wrote a highly influential textbook *On the Soul* (1552) in which he emphasized the compelling force of the human affects on human reasoning, but also recommended the value of anatomical studies, including Andreas Vesalius's *Fabric of the Human Body* (1543). This textbook of Melanchthon was used by the Calvinist Otto Casmannus, who in 1594 coined the term *anthropologia* for the general field to be further subdivided into *psychologia* and *somatologia*. In Melanchthon's many university orations he emphasized the value of the sciences from astronomy and astrology to medicine and psychology, both for the practical needs of society and for the theological contemplation of divine order in nature. Thereby Melanchthon placed natural philosophy in the context of a natural theology of Stoic flavor (Frank, 1999).

The impact of Lutheranism on science, however, is difficult to evaluate. Some argue that distrust in the a priori human reasoning led Melanchthon to a stronger empirical orientation (Kusukawa, 1995); others emphasize the traditional Aristotelian character of Melanchthon's philosophy of nature (Methuen, 1998). Some see the Lutheran emphasis on the Bible as disconnecting the Lutherans from any scientific interest (White, 1896, vol. 1); other interpreters see the careful literal reading of the Bible as a motivation for a likewise careful and unbiased study of the book of nature (Harrison, 1998). The case of astronomy may show the complexities. Nicolaus Copernicus's (1473–1543) *On the Revolutions of the Heavenly Spheres* was published in Tübingen in 1543 by the Lutheran theologian Andreas Osiander (1496–1552). In his preface Osiander declares Copernicus's work a fruitful hypothesis, though hardly literally true. Melanchthon was initially hostile to Copernicus, but later claimed "to love and admire Copernicus more." Even though Melanchthon could still not believe the theory to be literally true, he integrated the data and figures of Copernicus into the second edition of his 1562 book *Elements* (Barker, 2000). The Lutheran Copernican Johannes Kepler (1571–1630) came out of this astronomic school, and in 1616, when Copernicus's work was listed on the Papal Index of prohibited books, Copernicus appeared alongside the names of Luther, Erasmus, and Calvin.

Rather than seeking a global theory of a distinctive Lutheran involvement with science, it may be wiser to take one's departure in the observation that the Lutheran tradition in general takes a high view of nature, but a low view of disengaged reasoning. Whereas the Reformed and Anglican traditions highlight rationality (and played a major role in the emergence of classic physics), there are some affinities between Lutheranism and Romanticism. Both Georg Wilhelm Friedrich Hegel (1770–1831) and Friedrich Wilhelm Joseph von Schelling (1775–1854) were self-conscious Lutherans. Much later, Paul Tillich (1886–1965) explained how his own mystic and aesthetic attitude towards nature was nourished, via Schelling, by the Lutheran principle that the finite *is* capable of the infinite.

In this perspective it may be more than a coincidence that some of the most counterintuitive theories of modern science were produced by scientists working in a Lutheran milieu. In 1820 the Danish physicist Hans Christian Ørsted (1777–1851) discovered electro-magnetic force. In line with Schelling, Ørsted believed that the spiritual forces of attraction and repulsion are more basic than material particles, and their laws were claimed to reign in nature as well as in society. The quantum theory of the 1920s involved even more counterintuitive notions, and the embrace of paradoxical statements in the Copenhagen Interpretation by Niels Bohr (1885–1962) and Werner Heisenberg (1901–1976) was probably facilitated by a philosophical climate in which paradoxes could be better guides to truth than more pedestrian appeals to order and rationality. Bohr's indebtedness to Søren Kierkegaard (1813–1855) is an interesting case of a disguised presence of a religious tradition in the heuristics of science as well as in its subsequent interpretation.

There exists no official Lutheran view of the natural sciences, or worldviews. The general distrust in the project of natural theology (despite Melanchthon's legacy) is based on the prior conviction that the preaching of theology does not rely on particular philosophical or scientific foundations. Since the nineteenth century, Luther's doctrine of the two regiments (the spiritual and the secular) also led to a widespread assumption of an autonomy or *Eigengesetzlichkeit* (Max Weber) of the sciences. Rudolf Bultmann's (1813–1855) famous program of demythologization may count as one such example of separation. However, the conviction that natural processes are the "masks of God" present in creation has continued to prompt Lutherans to enter the science-religion dialogue. Since the 1980s significant initiatives have been taken by the German Evangelical Academies (Hans May, 1990), by the Evangelical-Lutheran Church of America (Mangum, 1989) and by the Lutheran World Federation (Mortensen, 1995). But in general the dialogue is left to individual scholars working in nondenominational settings.

See also CHRISTIANITY, HISTORY OF SCIENCE AND RELIGION; NATURAL THEOLOGY

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NIELS HENRIK GREGERSEN

CHRISTIANITY, ORTHODOX, ISSUES IN SCIENCE AND RELIGION

Historically, Orthodox Christianity dates back to the ancient Church, which was established by the apostles, powerful bishops, and seven Ecumenical Councils (from Nicea in 325 to Constantinople in 727). Orthodox Christianity considers itself as the "right" belief and "right glory," whose Church guards and teaches the true belief about God and represents the Church of Christ on Earth.

The divisions and fragmentation of the initially united Church led to the split of the Orthodox Church with Western Christianity, which is conventionally dated 1054 C.E. The Orthodox Church itself is divided into what can be called Oriental churches (mainly in Iraq and Iran), five non-Chalcedonian churches (in Armenia, Ethiopia, Egypt, and India; sometimes called *monophysite*), and the Eastern Orthodox churches proper.

In modern usage the term *Eastern Orthodoxy* is usually applied to those Christians who are in communion with the Ecumenical Patriarchate of Constantinople, which historically became restricted to the Greek-speaking world and later to other Slavic countries in Eastern Europe. There is no centralized organization in the Orthodox Church (unlike Roman Catholicism); it is a family of self-governing territorial bodies that are called Patriarchates. There are four Ancient Patriarchates and nine other autocephalous churches (the biggest one is the Russian Orthodox Church). All churches are in sacramental communion with each other. The territorial arrangement of the churches does not coincide with the formal boundaries of the states.

View of nature

Orthodox theology has a positive attitude towards the natural world as a good creation of a good God. Nature is never worshiped; it is God-creator who is worshiped through creation. The Fathers of the Church loved nature, but were never captured by the imagery of nature, which could prevent them from having a spiritual life in God. Thus nature was never considered an end in itself; its meaning and purpose can only be revealed in the perspective of Christ who, through the incarnation, recapitulated nature. The Fathers saw nature in the perspective of the hierarchy of the orders of creation, which proceeds from the natural law established by God. This "platonic" approach to nature could not provide any methodology of its investigation. The attitude to nature was speculative; it was interpreted in terms of laws that govern nature, but not their particular outcomes, which are displayed in a variety of phenomena. Nature, however, was never excluded from the general view of communion with God, so that the theology of the Greek Fathers was cosmic in its essence. Maximus the Confessor (c. 580-662) articulated that it is through communion with the Logos (Word) of God in Scriptures, through contemplation of the underlying principles of creation in nature, and in sacramental communion with Christ in Church that the fullness of communion can be achieved. Nature itself as the medium through which and by which communion with God can be established is seen as sacrament. Human being as microcosm and mediator participates in the cosmic Eucharist, which aims to renew and redeem the material world. Science then is treated as a tool to articulate the world in terms of its relationship with God.

Interaction with the sciences

In the first centuries of Christianity, the attitude to the sciences was established in the context of its encounter with classical Hellenistic culture. Since Clement of Alexandria (c. 150–215), philosophy and the sciences were considered human activities cooperating in ultimate truth, as useful tools in order to defend faith and make it demonstrable, and important for Christian education. The Greek Fathers asserted that scientific knowledge is incomplete in itself and must be supported by wider views of reality, which are accessible through faith. Knowledge and the sciences thus have their foundation in faith. Carried out through the centuries this attitude to science did not change, excluding any open conflicts between science and theology, with one exception—the seventy years of "scientific atheism" in Soviet Russia.

There is a perception among leading modern Orthodox theologians that science cannot be excluded from the theological vision of God and creation. The task of Orthodox theology is to reconcile the cosmic vision of the Fathers with the vision that grows out of the results of natural science.

The split between science and religion can be overcome on the grounds of their reinstatement to communion with God. Scientific work can be interpreted as "para-eucharistic" work (John Zizioulas). Scientific progress must be taken into account only in the context of the progress of human spirit and the deepening of human experience of the reality of the divine, which cannot be reduced to a physical or chemical level (Dumitru Staniloae). New conceptual tools for mediation between religion and science must be developed. The most important and urgent problems in the science-religion dialogue are not cosmological (e.g., creation of the universe) or philosophical (e.g., the meaning of evolution), but ecological and bioethical.

The Orthodox Church understands the modern ecological crisis either in terms of the misuse of science or utopian reliance on the power of progress. The Church consequently treats the crisis as essentially anthropological and spiritual. The message of the Church is to be cautious with scientific discoveries and technologies because they are handled by spiritually disorientated human beings, who have lost their roots in the divine. The loss of vision of the unity of the whole creation and human priestly responsibility for nature leads to abuse and degradation of the natural world, which threatens the very existence of humankind. It is in the context of love for nature, inner vigilance and chastity towards nature, and self-restraint in the consumption of natural resources that scientific activity can acquire some "eucharistic" features and nature can become reinstated to its sacramental status.

The Orthodox Church is deeply concerned with the possible moral and social implications of the fast advance of biology and medical science in terms of control and regulation of human life. For Orthodox Christians, life is the gift of God, who creates and preserves human personality. When biology and medicine interfere with human existence on the natural level, and threaten human integrity and personality, Orthodox theology opposes this on moral and social grounds. For example, the official position of the Church, expressed by the Council of Bishops of the Russian Church in 2001, with respect to cloning human beings is strongly negative on social grounds (the "printing" of people with specified parameters can appear welcome to adherents of totalitarian ideologies), as well as personal grounds (a clone can feel like an independent person, but it is only a "copy" of someone who lives or lived before). However, the cloning of isolated cells and tissues does not threaten the personality and can be helpful in medical practice. Genetic engineering is admissible with the consent of the patient in the case of some hereditary diseases, but the genetic therapy of germ cells is considered dangerous because it involves a change of the genome in the line of generations, which can lead to mutations and can destabilize the balance between the human community and the environment.

See also CLONING; ECOLOGY; GENETIC ENGINEERING; MEDICAL ETHICS

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ALEXEI NESTERUK

CHRISTIANITY, PENTECOSTALISM, ISSUES IN SCIENCE AND RELIGION

Describing overall Pentecostal attitudes and relationships to science is difficult given the diversity of the movement. What historians call *classical Pentecostalism* (denominational groups whose origins are traced back to the Azusa Street revival in Los Angeles from 1906 to 1908) does not adequately encompass the substantially diverse noninstitutional forms of the movement featured since its beginnings, including the development of its educational structure, much less its neo-Pentecostal aspects emergent since the charismatic renewal of mainline churches during the 1950s. Further, the predominance of oral over written modes of communication, especially among non-Western Pentecostal movements, means that specific documentary evidence regarding Pentecostal attitudes of laypersons to science is relatively meager.

Because of their otherworldly orientation, Pentecostals have been either relatively silent about or dismissive of the sciences. Administrators of Pentecostal institutions have had degrees in the humanities or in education, not in the natural sciences. Pentecostalism, being a missionary religion, felt little need for scientific involvement until the last half of the twentieth century. Some Pentecostals rejected scientific learning, based upon their limited perception of what science actually was, along with some aspects of society and culture as a whole. Yet other facets of the movement, including the emerging Pentecostal educational establishment, provide substantial evidence of growth in scientific studies and applications.

Creation and evolution

Otherworldly aspirations combined with a biblicist mindset and worldview, together with the expectation of the imminent return of Christ, fostered an anti-intellectualism among the vast majority of the first generation Pentecostals. Rather than pursuing a secular education or moving up the social ladder, most early Pentecostals were motivated ideologically primarily by evangelistic concerns, and secondarily by apologetic ones. Pentecostal Bible institutes were focused first and foremost on the development of pastors, missionaries, and church workers, and only minimally, if at all, on scientific education as a liberal art.

Science, insofar as it was understood by these Pentecostals, was an enemy of the faith, primarily because of the popularized claims of evolutionary biologists and paleontologists and their apparent presupposition of the nonexistence of God. At this point in Pentecostal development, these popular claims appeared indistinguishable from the methodology and interests of other branches of science, which were totally unknown territory. Since no Pentecostal expertise was available to sort out the details of experimental evidence and interpretation, the sciences did not seem safe. As with many Christians of their time, Pentecostals rejected the Darwinian theory of evolution as being antithetical to a literal reading of the biblical creation narratives. The widespread influence of the *Scofield Reference Bible* (1909) among early Pentecostals led many to adopt the *gap theory* of temporally ambiguous intervals between the Genesis narrator's "days." Unbeknownst to the Pentecostals, and probably to the writers of the *Scofield Bible,* this interpretation, or one of equating the "days" with temporally ambiguous periods, was equivalent to the mainstream of contemporary European Old Testament and Torah scholarship before, during, and after the introduction, in 1859, of Charles Darwin's speculative thesis with *The Origin of Species*.

Beginning in the 1930s and 1940s, a handful of second and third generation Pentecostals were drawn, out of curiosity and thoughtfulness, to study the sciences at universities, primarily biology, studies not encouraged by the elder generation. It began to dawn that medical missions created the need for biological sciences. At the same time, by distancing themselves from fundamentalism and affiliating with the emergent evangelical movement in the 1940s, Pentecostals purchased some social space for members of the movement interested in the sciences.

By the 1950s and 1960s, the initial avoid-and-reject mentality toward evolutionary biology remained among Pentecostal leaders but existed in tension with the discriminating worldview prevalent among the emerging group of college educated adherents. However, the acquisition of academic history by leaders in education, theology, or various humanities did not always erase an anti-intellectual and suspicious posture toward the sciences. Yet, Bible college and Bible institute educators and administrators sensed the need for providing an alternative "Pentecostal" program of study for Pentecostals desiring a college education. This led to the development of departments in the humanities and the sciences, and the offering of degrees in most of the liberal arts.

The scientific liberal arts, however, proved expensive to offer and did not command the enrollment and tuition dollars of other subjects. The quest for regional accreditation was a strong motivating force, but outside scrutiny and pressure did not overcome the traditional resistance to scientific competence. Faculty were sought with at least graduate, if not terminal, degrees in the humanities, mathematics, and the natural sciences, but the approach was, understandably, geared toward the primary realization that academic history had accreditational benefits. The established tradition in the world's universities and participating governments was that academic history, particularly in the natural sciences, is preparatory to the goal of academic production but this remained a totally unknown domain to Pentecostals. The established link between academic history and scholarly research and production, and between academic history, academic production, and teaching, would take at least another half century or more to be understood and become financially feasible at Pentecostal institutions. As Pentecostalism enters its second century, these scientific traditions are fairly well established at some of the leading Pentecostal institutions like Oral Roberts University (ORU) in Tulsa, Okalahoma, and Lee University in Cleveland, Tennessee.

Meanwhile, Pentecostal attitudes toward creation and macroevolution have continued to develop. The appearance of *Dake's Annotated Reference Bible* (1963) provided further "scientific evidence" for the gap or day-age interpretation already popular among many Pentecostals. The emergence of young earth creationism in fundamentalist and conservative evangelical circles caused alarm among Pentecostal science departments, and the Society for Pentecostal Studies was warned early on by the head of the science department at Lee university, Dr. Myrtle Fleming, to "distinguish between fact and theory, original works (experimental evidence), and philosopher's thinking" (Numbers p. 307). Pentecostal administrators have considered young earth creationism an embarrassment, with some institutions refusing to hire faculty in any discipline, scientific or otherwise, who adhere to this ideology. Many prominent Pentecostal evangelists and leaders have also opposed the Darwinian theory of evolution, while others have adopted literary understandings of the creation narratives that are harmonious with science. For many Pentecostal theologians and scientists the so-called theistic evolution (macroevolution with divine guidance) also appears incompatible both with biblical interpretation and with the experimental findings of modern science.

Yet, increasingly, Pentecostals educated in the sciences are suspicious about dogmatic approaches to superimposing macroevolution upon the physical evidence. There is emerging interest in paleontology, paleoastronomy, paleobiology, and paleogeology. Old style reactionary or rhetorical polemic from evolutionary biologists against the abrupt appearance of species, especially in light of the Cambrian explosion of life forms and, for example, the recent extraction of DNA from a hominid fossil, carries less weight among Pentecostal scientists and educators. As more and more Pentecostals are receiving graduate education and achieving doctoral degrees in the sciences, there is a sense in which the older creation-evolution debates are no longer an issue. New experimental results can now be assessed in an atmosphere where the hidden presupposition of the nonexistence of God is out in the open. The ongoing study of microevolutionary mechanisms, while rejecting ideologically motivated macroevolutionary changes per se until scientific evidence strongly suggests otherwise, is a responsible position taken by the majority of Pentecostal scientists. The ideology of carte blanche macroevolution not only contradicts much scientific evidence outright, but is imbued with unnecessarily confining naturalistic, atheistic, and Darwinian presuppositions that are no longer fashionable to many in the scientific community. Further, while contemporary Pentecostalism may host a few anomalous advocates of young earth creationism, it has made little headway among Pentecostals. Pentecostal, Orthodox, and Jewish interpretation is overwhelmingly in favor of understanding the "days" of the Genesis creation narrative as deliberately ambiguous and temporally indefinite periods. This is consistent with both cosmological observations and with the sudden appearance of diverse species in the extant fossil record as continually investigated by a number of scientific disciplines.

Pentecostalism and medical technology

Another window into the relationship between Pentecostalism and the sciences is provided by Pentecostal attitudes toward the use of medicine and the emerging medical establishment. The biblicism of early Pentecostalism led many to embrace the belief of divine healing insofar as this was explicitly connected with the New Testament practice of speaking in tongues (inspired speech in unlearned language, both human and divine, as conceptually interpreted in the book of Acts, and, differently, in the first epistle of Paul to the Corinthians). In part, given their lack of medical knowledge and the inaccessibility and unaffordability of medicinal supplies, early Pentecostals looked to God for their healing. As such, early Pentecostal attitudes toward medical practitioners and their arts resonated well with faith healer John Alexander Dowie's (1847–1907) widely circulated pamphlet, which identified the most dreaded disease as the "*bacillis lunaticus medicus*" (ridiculous bacteria of medicine). The result was that many sectarian Pentecostal groups, especially in the rural Appalachian part of America, rejected medicine and relied solely on the healing power of God, sometimes resulting in the loss of life.

Yet such early Pentecostal polemics were rampant against not only the emergent class of medical doctors, who often made mistakes and appeared unreliable to some, but also against the spiritual healing technologies of the Christian Science movement. Ironically, whereas North American Pentecostals were wary of combining faith and spiritual healing, throughout Asia, sub-Saharan Africa, and Latin America, Pentecostals have combined the belief in divine healing with shamanistic practices in order to address physical, emotional, and psychological ailments.

However, Pentecostals have always negotiated the tension between a robust belief in faith healing, which repudiated medical technology entirely, and the belief that faith healing and the use of medicine were indeed compatible. As Grant Wacker points out in *Heaven Below* (2001), medical doctors were found attending early Pentecostal revival services and even participating as members in Pentecostal communities of faith. Over the generations, both the upward social mobility of many Pentecostals and their medical missionary emphases led to an increasing acceptance of the use of medicine. In the 1970s, the establishment of a medical graduate program at ORU, a vanguard institution for neo-Pentecostal and charismatic higher education, followed soon after by their City of Faith Medical and Research Center, signaled the full engagement of the medical sciences among Pentecostals. Yet the ORU motto of educating "the whole man in spirit, mind and body" reflected at the same time the Pentecostal concern for holistic health care strategies. Unsurprisingly, then, polls conducted in the mid 1990s among Pentecostal ministers in Britain revealed that 93.7 percent believe that "modern medicine is a God-given blessing" (Kay, p. 121). It is fair to assume that this percentage is reflective at least of Western Pentecostal attitudes toward the medical sciences.

Arguably, given the emergence of the Pentecostal movement at the turn of the twentieth century, early Pentecostalism can be understood, at least in part, as a reaction to the scientific and technological rationality of that time. Glossolalia (speaking in tongues) is symbolic of the resistance of the masses against the hegemonic discourse of Enlightenment rationalism, as well as of a prayerful desire to be filled with the Holy Spirit. The belief in divine healing could be seen by sociologists as a protest against the failures of medical technology to heal the ills associated with the modernization and urbanization of the nineteenth century, as well as an appropriation of New Testament thought regarding spiritual gifts. As such, Pentecostal spirituality signifies an eruption in the Western world of the nonrational elements of human feeling, expression, and experience that opposes not the rational scientific methodology of science and engineering disciplines but the overextended popular claims of biological science.

In the meantime, however, the limits of scientific rationality have been recognized and acknowledged by the scientific community. For many, the impersonal is no longer preferred to the personal in the new "Era of the Glimpse of God" that began in 1965 with the paradigm-shifting discovery of the cosmic microwave background, followed by its spectacular finely tuned variations in 1992. This new era may have reopened the door for the dialogue that is taking place between humanities scholars in the inexact sciences who are studying Pentecostalism and between the many Pentecostals who are studying and practicing the various sciences. At the beginning of the second century of the Pentecostal "reformation," with over a million churches throughout the world, one of the classical Pentecostal institutions, the Church of God Theological Seminary in Cleveland, Tennessee, now offers a Master of Divinity and Doctor of Ministry course in Theology and Science.

See also CREATIONISM; SPIRITUALITY; SPIRITUALITY AND FAITH HEALING

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AMOS YONG
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CHRISTIANITY, RADICAL REFORMED, ISSUES IN SCIENCE AND RELIGION

The Radical Reformation began in Switzerland and southern German in the 1520s, when participants in the mainline Reformation objected to state control over churches. The Schleitheim Confession of 1527 was an attempt by Radical Reformers to distinguish their movement from other Protestants. The Radical Reform movement supported baptism for believers, separation from the world, selection of pastors from within the congregation, and the refusal to swear oaths. These elements were designed to nullify the effects of Constantinianism, the identification of the church first with empire and then with nation state.

The Radicals objected to the use of coercion and violence in the name of God. In this sense, they believed God's action in the human world to be noncoercive. Accordingly, they rejected violence and adopted the *ban* (exclusion from the shared life of the community in accordance with Matthew 18) as the most severe form of punishment. The Radicals continue to believe that Christianity has more to do with changing the world than interpreting its meaning, and therefore they have rarely engaged with scientific developments. Nevertheless, it can be argued that understanding God's action in the natural and social world as noncoercive has important consequences for interactions with the natural and social sciences.

When Isaac Newton's (1642–1727) Laws were accepted as a complete account of all the movements of matter in the universe, it became difficult to conceive of God's action in the world. Modern liberal and conservative views differed over characterizations of divine action. Liberal theologians generally rejected the concept of special divine acts because it seemed self-contradictory for God to break natural laws. Conservative theologians, on the other hand, generally accepted that God could and did miraculously break into the natural causal order. By contrast, Radical Reformed theologians claimed that while God does act in the world, God does so noncoercively. With developments in quantum physics, it has become easier, though still not unproblematic, to make sense of this claim. For example, it would not be inconsistent, or coercive, for God to manipulate quantum events since it is widely agreed that there is no self-determination at this level for God to overrule.

Whereas conflict with the natural sciences has not been an issue for Radical Reformed theologians, there are inherent tensions between Radical Reformed thought and modern social science because of the movement's attempt to embody the Sermon on the Mount. From the early modern period, the dominant assumption in social science has been that coercion, and ultimately violence, is necessary to maintain order in society. However, according to the Radical Reformed view the church itself provides empirical evidence that a society based on noncoercive reconciliation is possible. The church can be understood as an experiment whose existence demonstrates that violence is not a necessary part of social relations. From this perspective, a new vision can emerge for society and social science. One concrete example is Jesus' rejection of retribution as a model for justice in the Sermon on the Mount. In its place, the sermon provides for an understanding of justice that focuses on reconciliation and restoration.

See also CHRISTIANITY, ANGLICAN, ISSUES IN SCIENCE AND RELIGION; CHRISTIANITY, EVANGELICAL, ISSUES IN SCIENCE AND RELIGION; CHRISTIANITY, LUTHERAN, ISSUES IN SCIENCE AND RELIGION; CHRISTIANITY, ORTHODOX, ISSUES IN SCIENCE AND RELIGION; CHRISTIANITY, PENTECOSTALISM, ISSUES IN SCIENCE AND RELIGION; CHRISTIANITY, REFORMED, ISSUES IN SCIENCE AND RELIGION; CHRISTIANITY, ROMAN CATHOLIC, ISSUES IN SCIENCE AND RELIGION; SCIENCE AND RELIGION, HISTORY OF FIELD

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CHRISTIAN EARLY
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CHRISTIANITY, REFORMED, ISSUES IN SCIENCE AND RELIGION

The term *Reformed theology,* though sometimes used synonymously with *Calvinism,* refers more broadly to doctrines traceable to a group of sixteenth-century reformers that included Guillaume Farel (1489–1565), John Calvin (1509–1564), Huldrych Zwingli (1484–1531), Heynrich Bullinger (1504–1575), John Knox (1505–1572), and, arguably, Johannes Bucer (1491–1551) and Peter Vermigli (1500–1562). Nonetheless, it was Calvin in the various editions of his *Institutes of the Christian Religion* (1536–1560) who more than anyone set the main trajectories of Reformed theology.

Early reformed senses of nature

Calvin likens Scripture to spectacles by which one can read the benevolent purpose of creation, which includes both the delight and the utility of nature. There is no suggestion that Calvin thought Scripture was a substitute for physical inquiry regarding matters of what are today called the natural sciences. At the same time, there is no evidence that he closely followed the latest scientific discoveries; his relative indifference to the work of Nicolaus Copernicus (1473–1543) is itself, in retrospect, a glaring omission. The necessities of international diplomacy for the Reformed movement, its political theory and practice, demanded more of his attention than did the astronomy of the time. Calvin still worked within a framework that resisted the notion that the Earth moved. He never reached the point of Thomas Digges (d. 1595), who argued that such a movement within a huge expanse of extremely distant stars redounded to God's glory. Digges belongs to that significant group of people active in the transition from a modified Aristotelian natural philosophy to a Newtonian physics. Gisbert Voetius (1589–1676), who sought to hone his particular version of Aristotelianism and who argued for proscribing the writings of René Descartes (1596–1650), was a kind of throwback. That exception, however, is far outweighed by the works of one of the great forerunners of modern science, Francis Bacon (1561–1626), and of Isaac Newton (1642–1727).

The senses in which the word *nature* and its several translations are used by Reformed theologians are even more numerous than those inherited from classical antiquity and the early church. The best way, drawing on Ronald Hepburn in "Philosophical Ideas of Nature" (1967), of getting at this usage is to note the analogies the Reformed theologians chose to deal with the perennial questions about fundamental reality comprising the world and its structure. Those questions are regarded as perennial largely because of the opulence of analogies used by different streams of classical philosophy: geometrical and mathematical analogies in the case of Anaximander and Pythagoras, archetypal and intellective analogies in the case of Plato, organic and motional in the case of Aristotle, cosmic and cyclical in the case of the Stoic philosophers. In these discussions, the terminology was richly varied, especially when translated from one language to another. The word *natura* sometimes translated *physis* ("nature"), sometimes *ousia* ("being"); sometimes *substantia* ("substance") translated them both. When used in Christian doctrine, a workable agreement about several major terms was achieved by the time of the Council of Chalcedon (451), whereby in the West *persona* ("person") translated *hypostasis* ("way of being"), *substantia* translated the unique *ousia* of the Trinity, and *naturae* translated the two *physeis* united in the incarnation. Even so, the so-called monophysite controversy (over whether the one person Jesus Christ had only one nature) showed that this usage was not universally accepted. Each of the main terms had its own history during the course of medieval philosophy.

Nature and grace in reformed orthodocy

Following one medieval tradition, Reformed theologians sometimes used the term *nature* in contrast to *grace,* sometimes as a synonym for the whole of creation including human life, and sometimes as a synonym for the whole of creation excepting human life. What seems best to characterize their view of nature is that they could draw on any of a number of analogies, so long as the analogies served a view of the universe as that which is created by God out of nothing and is providentially sustained for an ultimately good end. Or, to put it another way, benevolent teleology governed their cosmology in such a way that critical inquiry into the basic structure of reality was encouraged. In their history of interpretation, they read 2 Corinthians 4:6 as making the connection between the human nature united to the eternal word in the incarnation and nature as the whole cosmos brought into being by God's efficacious word: "It is God who said 'Let light shine out of darkness,' that has shone into our hearts to enlighten them with the knowledge of God's glory, the glory on the face of Christ." According to Johann Heinrich Heidegger (1633–1698), the reason God created was to share his love with another. In this way God can be called *natura naturans* (nature which brings about nature), the uncaused cause who created *ex nihilo* (out of nothing) the *natura naturata* (nature thus brought about), including the secondary causes through which God's providentially sustaining word works. The intricacy, order, and beauty of the universe thus benevolently created and sustained (as "creation continued") provided motivation for the study of nature in which the Reformed theologians were convinced that the hand of God could be discerned; that is, the wondrous correlation between the microcosm and the macrocosm helped provide the kind of validation in which physical experimentation, done with a variety of analogical worldviews, would flourish.

This use of the primary-secondary causes scheme, largely developed to claim simultaneously God's all inclusive providence and a measure of creaturely initiative, came to be radically challenged. However, depending on who was using the scheme, it could function to encourage physical investigation. Heidegger, in his 1696 treatment of divine concurrence, pushed this idea to provide an intriguing argument for physical inquiry. To discover order in events necessarily predictable according to natural laws is, of course, commendable; " … but God's providence is manifested particularly in things contingent" (Heppe p. 248) God alone, says Heidegger, already understands these "uncertain and casual" events which are the subjects of investigation. The distinction between explicable ("natural or necessary") events and events that are not yet explicable ("casual and fortuitous") was proving, with more physical experimentation, to be merely formal. Rather than detracting from providence, the discoveries of greater complexity and diversity were thought especially to bear witness to divine teleological benevolence. For example, according to Reformed theologians like Heidegger, God's glory is more manifest by creation developing over a period of time (creation continued after the singular creation out of nothing) than by a supposedly instantaneous completion. This argument resurfaced later against those who, unnerved by the discoveries of evolutionary biology and geology, insisted on a literal interpretation of the creation accounts in Genesis.

Reformed responses to nineteenth-century science

There was a considerable range of mutual influence between Reformed thinkers and the rise of modern geology, paleontology, and evolutionary zoology, and two contrasting reactions developed. The first was the reaction of two figures at Yale: James Dwight Dana (1813–1895), professor of geology, and Theodore Dwight Woolsey (1801–1889), the Yale president. Both stood in the broader Calvinist tradition tempered by the Reawakening at the hands of Jonathan Edwards (1703–1758) a century earlier. Dana found no fundamental incompatibility between the evidences for Christian doctrine and evidences for evolution, though he disagreed with Darwin's theory of single-line evolution and corresponded with Darwin about it. Dana expressed these ideas on March 29, 1890, in a lecture entitled "The Genesis of the Heavens and the Earth." Woolsey warned against the threat of positivism and secularization, rather than specifically against the work either of Charles Darwin (1809–1882) or Herbert Spencer (1820–1903).

By contrast, the second reaction was represented by the theologian Charles Hodge (1797–1878) of Princeton, whose particular belief in Biblical inerrancy, including the Genesis accounts of creation, led him finally to oppose Darwinism as he understood it. He expressed his ideas in *What is Darwinism?* (1874) However, Hodge's apologetic counterargument, carried on with an irenic intent not always evident in his followers, was made with what he thought to be the tools of a more valid scientific method. That is, while he opposed Darwin's findings, Hodge himself believed that scientific argument was not opposed to the brand of Calvinism that he represented and that was heavily shaped by the earlier work of Francis Turretin (1623–1687).

Reformed theology and post-Newtonian physics

With the displacement of Newtonian physics came a new era in which the attention shifted from debates over evolution and Genesis to the implications of post-Newtonian physics for Reformed theology and of Reformed theology for honing questions of scientific method. One major development is represented by the recovery of the seriousness with which theology is to be taken as a science. Such an approach does not mean, as it did with nineteenth-century apologetic theology, an attempt to legitimate theology by arguing its similarity to natural science; rather, it means considering theology as a science in the sense that it has its own procedures congruent with the subject matter being studied. Although the tradition of defining theology as a science had never died out, now there was a recovery of the boundaries and the mutual respect necessary to fruitful dialogue. In this, and in many other aspects of theology and culture, Karl Barth (1886–1968) was a leader, though his influence in shaping the content of the dialogue between Reformed theology and the natural sciences was indirect. It was left to others, especially the Scottish theologian Thomas Torrance (1913–) whose study of James Clerk Maxwell (1831–1879), Albert Einstein (1879–1955), and Michael Polanyi (1891–1976) led him to explore analogies between scientific knowledge and theological knowledge and between theories of relativity and dynamic redefinitions of being. Torrance called attention to Athanasius (c. 296–373) and the Cappadocians (Basil the Great, c. 330–379; Gregory Nazianzus, 329–389; and Gregory Nyssa, c. 330–c. 395) whose relational understanding of God's triune nature has provided material for discussions between theologians and contemporary physicists. Representative of the discussion is Torrance's *Transformation and Convergence in the Frame of Knowledge* (1984). James Loder and James Neidhardt pursued this line further, as did Harold Nebelsick from the perspective of a historian of science.

See also CHRISTIANITY; CREATIO CONTINUA; CREATIO EX NIHILO

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E. DAVID WILLIS

CHRISTIANITY, ROMAN CATHOLIC, ISSUES IN SCIENCE AND RELIGION

The most distinctive features of Roman Catholicism that influence the religion-science dialogue are its hierarchical and authoritative structure and its emphasis upon the rational foundations for religious belief. Many of the divisions that have occurred within Christianity in the course of history have their origins in one or both of these characteristics of Roman Catholicism. The history of the interaction within Roman Catholicism between science and religion has been dominated by its hierarchical structure. On the other hand the insistence on reason as fundamental to the relationship of human beings to the universe and, therefore, to the creator of the universe has played an important role in the birth of modern science and provides a platform for the dialogue between the belief system of Roman Catholicism and other disciplines, especially science.

Views of nature

The Catholic belief system includes the fundamental affirmation that nature has a rational structure which human intelligence is capable of probing and, in fact, is driven to probe. The basis for this affirmation lies principally in the Johannine tradition of the *Logos.* John the Evangelist confronted early Christian belief with the world of Greek philosophy. In addition, early Christian reflection upon lived, historical events, especially those recorded in John's Gospel, sees in such events the insertion of God's plan, thought, and word into the universe. Thus John's use of the word Logos, inherited from the Greeks: "The Word (Logos) of God became flesh." This revelation, which the Judeo-Christian tradition believes is spoken by God through his chosen spokespersons, has enormous consequences for one's judgment upon scientific knowledge of the universe. The Judeo-Christian experience affirms emphatically the enfleshment of the divine and, since God is the source of the meaning of all things, that meaning too becomes incarnate.

Some see in this religious belief the foundations of modern science. A rigorous attempt to observe the universe in a systematic way and to analyze those observations by rational processes, principally using mathematics, will be rewarded with understanding because the rational structure is there in the universe to be discovered by human ingenuity. Since God has come among human beings in his Son, humans can discover the meaning of the universe, or at least it is worth the struggle to do so, by living intelligently in the universe.

Religious experience thus provides the inspiration for scientific investigation.

To varying degrees this "Logos theology" is at the roots of all Christianity. What in it is peculiar to Roman Catholicism? In addition to the strong affirmation of this "transcendence become incarnate" by the robust system of sacraments in Roman Catholicism (shared, perhaps, also by Anglicanism), there is in Catholicism a long tradition of analogical knowledge. This reached its peak in medieval Scholasticism, and, although it has taken on many forms, is still very prominent in Catholic thought. It seeks to come to a knowledge of God, the creator, through knowledge of creation. In creation, perfections are always mixed with imperfections. If, at least in thought, the two can be separated, the perfect can then be applied to God. This analogical knowledge is also referred to as the *via negativa* because, even as one applies knowledge of the perfect to God, one must deny that God can be limited to this knowledge. So, the philosopher Thomas Aquinas (c. 1225–1274) could rightly say upon the completion of his *Summa Theologica* that "it was all straw."

Analogy refers to a relationship of similitudes, or of things that are similar. For instance, God is perfect love, and that can be compared with other kinds of love that one witnesses, such as the love of a mother for her child, or the long-standing love of a husband and wife for one another in a stable marriage. But then one sees imperfections in human love, and one must deny that these are present in God's love. That is the use of analogy. The implication is that God wishes to tell humans about himself/herself in creation. It follows, therefore, that a scientist, one who is also a religious believer, must find in science one way to seek to know God. Roman Catholicism in its view of nature is profoundly convinced of this.

It is important to note the logical sequence here. It is not that one comes to believe in God by proving God's existence through anything resembling a scientific process. God is not found as the conclusion of a rational process like that. One believes in God because God gave himself/herself to one. Faith is a personal relationship of love with God and God initiated gratuitously that relationship. No one merited it. No one reasoned to it. Faith is "arational." It does not contradict reason, but it transcends it. Once one has entered into that relationship, one can seek to deepen it through a scientific knowledge of God's creation. This is a very characteristic stance of Catholic intellectuals.

History of the interaction between science and religion

Because of the dominant hierarchical and authoritative structure of the Catholic Church the history of the interaction between science and religion will necessarily focus upon that structure. This is not to deny that influential Catholic thinkers, such as the paleontologist Pierre Teilhard de Chardin (1881–1955), the astronomer and cosmologist George Lemaître (1894–1966), and others, have not had an impact, but they are not typical of Catholicism in regard to the interaction with science.

Four case histories indicate that the relationship between religion and science in Roman Catholicism has, in the course of three centuries, passed from one of conflict to one of compatible openness and dialogue. The four periods of history are: (l) the rise of modern atheism in the seventeenth and eighteenth centuries; (2) anticlericalism in Europe in the nineteenth century; (3) the awakening within the Church to modern science in the first six decades of the twentieth century; and (4) the Church's view at the beginning of the twenty-first century. The approach of science to religion in each of these periods can be characterized respectively as: (l) temptress, (2) antagonist, (3) enlightened teacher, (4) partner in dialogue.

In his detailed study of the origins of modern atheism, Michael Buckley concludes that it was, paradoxically, precisely the attempt in the seventeenth and eighteenth centuries to establish a rational basis for religious belief through arguments derived from philosophy and the natural sciences that led to the corruption of religious belief. Religion yielded to the temptation to root its own existence in the rational certitudes characteristic of the natural sciences. This rationalist tendency found its apex in the enlistment of the new science, characterized by such figures as Isaac Newton (1642–1727) and René Descartes (1596–1650), to provide the foundation for religion. Isaac Newton marks the real beginning of modern science. Although the Galileo case, as it is called, provides the classic example of confrontation between science and religion, it is really in the misappropriation of modern science by Isaac Newton and others to mistakenly establish the foundations for religious belief that the roots of a much more deep-seated confrontation can be found. From these roots, in fact, sprung the divorce between science and religion in the form of modern atheism. Thus, science served as a temptress to religion. The certainties born of the scientific method gave birth to the desire for identical certainties as a foundation for religious belief. That desire was radically misplaced and led to a lengthy period of misunderstanding between religion and science.

Certain episodes during the nineteenth century reveal aspects of the second movement—anticlericalism. Its influence on the development of the relationship between science and religion in Catholicism are described by Sabino Maffeo in the second edition of his history of the Vatican Observatory. In fact, the founding of the Observatory in 1891 by Pope Leo XIII is set clearly in that climate of anticlericalism, and one of the principle motives that Leo XIII cites for the foundation of the Observatory is to combat such anticlericalism. However, after having shown clearly the prevailing mistrust of many scientists for the Church, he terminates the document in which he established the Observatory by stating:

> . . . in taking up this work we have put before ourselves the plan … that everyone might see that the Church and its Pastors are not opposed to true and solid science, whether human or divine, but that they embrace it, encourage it, and promote it with the fullest possible dedication (quoted in Maffeo, p. 315 ff.)

Although the historical circumstances did not provide a healthy climate for a dialogue between religion and science, the founding of the Vatican Observatory, even if couched in triumphalistic terms, proved to be a positive contribution to the dialogue, both at the time of its foundation and in its subsequent history.

When one speaks of the awakening of the Church to science during the first six decades of the twentieth century, one is really speaking of the personage of Pope Pius XII. The Pope had an excellent college-level knowledge of astronomy and he frequently discussed astronomy with researchers. However, he was not immune to the rationalist tendency and his understanding of the then most recent scientific results concerning the origins of the universe led him to a somewhat concordant approach to seeing in these scientific results a rational support for the scriptural, and derived doctrinal, interpretation of creation. It was only, in fact, through the most delicate but firm interventions of Georges Lemaître, the father of the theory of the primeval atom that foreshadowed the theory of the Big Bang, that the Pope was dissuaded from following a course that would have surely ended in disaster for the relationship between the Church and scientists.

The specific problem arose from the tendency of Pope Pius XII to identify the beginning state of the Big Bang cosmologies, a state of very high density, pressure, and temperature, which was, at that time, thought to have occurred about one to ten billion years ago, with God's act of creation. Lemaître, in particular, had considerable difficulty with this view. Although he was a respected cosmologist, he was also a Catholic priest, and, since solid scientific evidence for his theory was lacking at that time, he was subject to the accusation that his theory was really born of a spirit of concordism with the religious concept of creation. In fact, it was only with the discovery in 1965 of cosmic background radiation that persuasive scientific evidence for the Big Bang became available. Lemaître insisted that the primeval atom and Big Bang hypotheses should be judged solely as physical theories and that theological considerations should be kept completely separate.

Galileo and Darwin

There are two episodes in the history of the interaction between Catholicism and science that merit special attention. The cases of Galileo Galilei (1564–1642) and Charles Darwin (1809–1882) have, at least in the popular mind, become myths that are thought to exemplify the interaction.

In view of Galileo's increasing promotion of Copernicanism the Congregation of the Holy Office of the Catholic Church in 1616 issued a decree that declared that the Copernican theory that the sun moved was absurd in philosophy and heretical, and the theory that the Earth was not immovable was absurd in philosophy and suspect of heresy. These carefully honed distinctions between philosophy and religious belief reveal the exaggerated rationalism of Catholicism at that time. *Philosophy,* of course, referred to the philosophy of nature, what people today call *physics. Heretical* meant that the philosophy contradicted Scripture. The physics was that of Aristotle; Scripture was limited to the literal meaning and to the understanding of the Church Fathers. On both accounts the decree was, by hindsight, grossly in error. This is touted as a conflict between science and religion, but of all things it was clearly not that. Science was never a partner in the discussions. Galileo's telescopic observations, which convincingly supported Copernicanism even though they were not proofs, were never subjected to discussion. Furthermore, religion in the name of Scripture was not a principal protagonist. A philosophical conviction that Aristotle was correct led to an insistence on a literal interpretation of Scripture. Uncritical and untested convictions about the nature of the universe dominated the scene on the part of the Church. In 1633 Galileo was condemned to house arrest for life because he had disobeyed, by his publication of the *Dialogue,* a private edict given to him in 1616, as a consequence of the above decree, not to support Copernicanism. A final judgment upon this case must be that the Church erred gravely at that time in not allowing an internationally renowned scientist to pursue his research. It did so because its authoritarian structure embraced a renunciation of reason. Aristotelian natural philosophy was the standard, not because it was reasonable but because it was imbedded in all Catholic theological thinking of that epoch. A fracture had occurred between reason and authority, two basics of the Catholic way.

The case of Darwin is different; in confronting Darwinian evolution, it was Catholic doctrine that was at stake. There are two fundamental doctrinal assertions that appeared to be under attack: The human being is a special creature, in whose origins God directly intervenes; and the supernatural cannot be reduced to the natural.

Since the time of Darwin, as biological, chemical and physical evolution became ever more acceptable scientifically, the Catholic Church has struggled to understand its doctrinal heritage in light of the new science. On October 22, 1996, a message of John Paul II on evolution was received by the members of the Pontifical Academy of Sciences on the occasion of a meeting sponsored by the Academy on *The Origin and Evolution of Life.* This message is in continuity with the posture of openness characteristic of modern Catholicism. Whereas the encyclical of Pope Pius XII in 1950, *Humani Generis,* considered the doctrine of evolution a serious hypothesis, worthy of investigation and in-depth study equal to that of the opposing hypothesis, John Paul II states in his message:

> Today almost half a century after the publication of the encyclical [*Humani Generis*], new knowledge has led to the recognition that the theory of evolution is no longer a mere hypothesis.

The Pope wished to recognize the great strides being made in the scientific knowledge of life and the implications that may result for a religious view of the human person. For him, however, some theories of evolution are incompatible with revealed, religious truth. These include materialism, reductionism, and spiritualism. But at this point the message embraces a true spirit of dialogue when it struggles with the opposing theories of evolutionism and creationism as to the origins of the human person. And this is obviously the crux of the message.

The dialogue progresses in the following way: (1) The Church holds certain revealed truths concerning the human person; (2) Science has discovered certain facts about the origins of the human person; (3) Any theory based upon those facts that contradicts revealed truths cannot be correct. Note the antecedent and primary role given to revealed truths in this dialogue; yet note the struggle to remain open to a correct theory based upon the scientific facts. The dialogue proceeds between these two poles. In the traditional manner of papal statements, the main content of the teaching of previous popes on the matter at hand is reevaluated. And so the teaching of Pius XII in *Humani Generis* that, if the human body takes its origins from preexistent living matter, the spiritual soul is immediately created by God. Is the dialogue therefore resolved by embracing evolutionism as to the body and creationism as to the soul? It must be noted that the word *soul* does not reappear in the remainder of the dialogue. Rather the message moves to speak of "spirit" and "the spiritual."

If the revealed, religious truth about the human being is considered, then there is an ontological leap or an ontological discontinuity in the evolutionary chain at the emergence of the human being. Is this not irreconcilable, wonders the Pope, with the continuity in the evolutionary chain seen by science? An attempt to resolve this critical issue is given by John Paul II's statement in his 1996 message that:

> The moment of transition to the spiritual cannot be the object of this kind of [scientific] observation, which nevertheless can discover at the experimental level a series of very valuable signs indicating what is specific to the human being.

The suggestion is being made, it appears, that the ontological discontinuity may be explained by an epistemological discontinuity. Is this adequate or must the dialogue continue? Is a creationist theory required to explain the origins of the spiritual dimension of the human being? Are we forced by revealed, religious truth to accept a dualistic view of the origins of the human person, evolutionist with respect to the material dimension, creationist with respect to the spiritual dimension? In the last paragraphs concerning the God of life, the message gives strong indications that the dialogue is still open with respect to these critical questions.

The dialogue at the beginning of the twenty-first century

Although there are many others, the sources for deriving the most recent view from Roman Catholicism concerning the relationship of science and faith are essentially three messages of John Paul II, two of them given in 1979 and 1986 to the Pontifical Academy of Sciences, and the third in 1988 to the Vatican Observatory. The public has emphasized the statements made by the Pope concerning the Copernican-Ptolemaic controversy of the seventeenth century. In his statements concerning Galileo the Pope essentially does two things: He admits that there was wrong on the part of the Church and apologizes for it, and he calls for a serene, studious, new investigation of the history of that time. However, there are matters that are much more forward-looking and of much more significance than a reinvestigation of the Galileo case.

Especially in the 1988 message, given on the occasion of the tricentennial of Newton's *Principia Mathematica,* John Paul II clearly states that science cannot be used in a simplistic way as a rational basis for religious belief, nor can it be judged to be by its nature atheistic or opposed to belief in God.

> … Christianity possesses the source of its justification within itself and does not expect science to constitute its primary apologetic. Science must bear witness to its own worth. While each can and should support the other as distinct dimensions of a common human culture, neither ought to assume that it forms a necessary premise for the other. (quoted in Russell et al., p. M9).

The newest element in this view from Rome is the expressed uncertainty as to where the dialogue between science and faith will lead. Whereas the awakening of the Church to modern science during the papacy of Pius XII resulted in a too facile an appropriation of scientific results to bolster religious beliefs, Pope John II expresses the extreme caution of the Church in defining its partnership in the dialogue: " … Exactly what form that (the dialogue) will take must be left to the future" (quoted in Russell et al., p. M7).

See also DARWIN, CHARLES; GALILEO GALILEI; SCIENCE AND RELIGION, MODELS AND RELATIONS; TEILHARD DE CHARDIN, PIERRE

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GEORGE COYNE

CHRISTOLOGY

In the Septuagint, the Hebrew word *Messiah* is translated *Christos,* the anointed one. Since the Christian community believed that Jesus of Nazareth was the anointed one, *Christology* is then the teaching about Jesus of Nazareth as the Christ. Prior to Jesus, there were various Jewish hopes of a new age, often involving intermediary or redeemer figures. The Christian community focused these hopes in Jesus of Nazareth, and consequently proclaimed him as the Christ. In the second century, Ignatius could then talk about "our God, Jesus Christ" (Eph. 18:2; Rom. 3:3) implying a unity between God and Christ. Christians believe that the reason for this elevated status of Christ comes through his resurrection because, as Paul claims, "if Christ has not been raised, then our proclamation has been in vain and our faith has been in vain" (1 Cor. 15:14).

For Christians, Jesus' resurrection indicated a duality of the risen one. Jesus "was descended from David according to the flesh," but he was also "declared to be Son of God with power according to the spirit of holiness by resurrection from the dead" (Rom. 1:3–4). Through his resurrection Jesus became the Son of God who stands beside his Father and participates in the power the Father delegated to him. According to Christians Jesus became the Lord of all and the resurrection became the foundation of Christology.

The Christian belief that Jesus is the Christ entails a connection between Christology and the origin, structure, and destiny of the physical world. In the opening sentences of John's Gospel, a rephrasing of the Genesis priestly creation account occurs. "In the beginning was the Word [*Logos*], and the Word was with God, and the Word was God. He was in the beginning with God. All things came into being through him and without him, not one thing came into being" (John 1:1–3; cf.Gen. 1:1). John asserted that Jesus' coming as the redeemer provides an exact parallel to the creation. Moreover, the Logos, similar to the Jewish personification of wisdom, is the mediator of this new creation, as the Logos was the mediator of creation at the beginning of time. In Jesus, "the Word became flesh and lived among us" (John 1:14). This emphasis on Christ as the first-born of all creation and its mediator is expressed again in Colossians 1:15–17, which states that Christ is not only prior to all creation, but also that all earthly and cosmic powers were created through and for him.

Christ is also presented as the goal of creation and as being present in creation. Underlying this claim, affirmed as early as Justin Martyr (c. 100–165), is the identification of the Logos with reason. So taught the Stoa (initially a Greek school of philosophy), the implications of which were that creation was understood as both reasonable and governed by God as manifested in Jesus Christ. It also allowed Christians to accept whatever they found reasonable in non-Christian insights, such as in Greek philosophy.

Paul Tillich (1886–1965) picked up this correspondence of the universal and incarnate Logos in the twentieth century. Delineating the respective tasks of theology and philosophy, however, Tillich states that theologians do not use the universal Logos as their source of knowledge. Rather, the Logos became flesh, manifesting itself in a particular historical event. The medium through which theologians receive the Logos is not reason but the church, its traditions and its present reality.

Although Paul did not develop general cosmic or metaphysical speculations (1 Cor. 8:6), he did concentrate on the meaning of Christ's lordship. Since Adam was "a type of the one who was to come," the righteousness of Jesus "leads to justification and life for all people" (Rom. 5:18), and therefore nothing "in all creation" can separate human beings from "the love of God in Christ Jesus our Lord" (Rom. 8:12–39). For Paul, God exalted Jesus that at his name "every knee shall bow, in heaven and on earth, and under the earth" (Phil. 2:9–11). In and through and for Jesus all things were created, and "by the blood of the cross" all things can be reconciled to Jesus (Col. 1:15–20). This means that personal salvation and the salvation of the whole world are tied together.

With reference to Colossians 1:15–20, at the Third Plenary Assembly of the Ecumenical Council of Churches at New Delhi, India, in 1961 the Lutheran theologian Joseph Sittler (1904–1987) referred to the cosmic Christ, claiming that "a doctrine of redemption is meaningful only when it swings within the larger orbit of a doctrine of creation. For God's creation of earth cannot be redeemed in any intelligible sense of the word apart from a doctrine of the cosmos which is his home, his definite place, the theatre of his selfhood under God, in corporation with his neighbor, and in caring-relationship with nature, his sister" (Sittler, p. 179). Since nature and humanity are threatened by annihilation, it is not plausible, according to Sittler, to proclaim Christ as the light of the world without incorporating the natural world into that proclamation.

The Jesuit paleontologist Pierre Teilhard de Chardin (1881–1955) picked up the concept of a cosmic Christ, claiming in his essay "Note on the Universal Christ" that "the universal Christ of the New Testament is the organic center of the entire universe" (p. 14). If Christ is universal, Teilhard concludes, then redemption and the fall must extend to the entire universe. Therefore the whole of evolutionary activity is centered in a process of communion with God.

Finally, process theology picked up the notion of a cosmic Christ. In *Christ in a Pluralistic Age* (1975), John B. Cobb, Jr. (1925–) claimed: In the Christian tradition "the Logos is the cosmic principle of order, the ground of meaning, and the source of purpose, and is identified with the incarnate form of the transcendent reality, the Christ" (p. 71). From this he concludes: "Christ is the incarnate Logos. As such Christ is present in all things" (p. 142). Since the Logos is the order, "Apart from Christ there is no hope for a better future" (p. 186).

See also TEILHARD DE CHARDIN, PIERRE

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HANS SCHWARZ

CLOCKWORK UNIVERSE

Clockwork universe refers to the concept of the universe as a system that behaves in a manner as patterned and dependable as a mechanical clock. Like a clock, the universe could be thought of as something both designed and constructed—something both conceptualized by a divine artificer and made by a divine craftsman. Like a clock, the universe, once set in motion by its creator, could be visualized as something able to operate without corrections or interference from outside. The regular motions exhibited by the sun, moon, stars, and planets provided the basis for elaborate medieval clocks that could mimic the patterned motion of these celestial objects.

See also DEISM; DETERMINISM; DIVINE ACTION; DOUBLE AGENCY; NEWTON, ISAAC; PHYSICS, CLASSICAL; PROVIDENCE; SPECIAL DIVINE ACTION

HOWARD J. VAN TILL

CLONING

Cloning burst upon the scene in February, 1997, with the announcement of the birth of Dolly, the cloned sheep. She was created when researchers took the DNA nucleus from a cell of an adult sheep and fused it with an egg from another sheep. Shortly after Dolly was born, mice, cattle, goats, pigs, and cats were also cloned.

For biologists, however, the word *cloning* refers not to producing new animals but rather to copying DNA, including short segments such as genes or parts of genes. This ability to copy DNA is a basic technique of genetic engineering used in almost every form of research and biotechnology. In Dolly, copying was taken to the ultimate scale, the copying of the entire nucleus or the entire genome of the sheep. The transfer of the nucleus is usually called *somatic cell nuclear transfer* (SCNT), and this is what most people have in mind when they speak of cloning.

Dolly's birth immediately raised the question of human cloning. In principle, a human baby could be made using SCNT. The technical obstacles are, however, greater than most people recognize. Experts in the field doubt that human reproductive cloning can be safely pursued, at least for several decades. In Dolly's case, it took 277 attempts to create one live and apparently healthy sheep, a risk level that is clearly unacceptable for human reproduction. More important, the state of Dolly's health is not fully known. One fear associated with cloning is that the clone, having nuclear DNA that may be many years old, will age prematurely, at least in some respects. Mammalian procreation is a profoundly complicated process, as yet little understood, with subtlety of communication between sperm, egg, and chromosomes, which allows DNA from adults to turn back its clock and become, all over again, the DNA of a newly fertilized egg, an embryo, a fetus, and so forth through a complex developmental process. Using cloning to produce a healthy human baby who will become a healthy adult is decidedly beyond the ability of science as of 2002. Expert panels of scientists all strongly condemn the use of SCNT to produce a human baby.

Therapeutic cloning

Cloning, however, may have other human applications beside reproduction, and many scientists endorse these. Usually such applications are referred to as *therapeutic cloning,* but it should be noted that much research must occur before any therapy can be achieved. Especially interesting is the possibility of combining nonreproductive cloning with embryonic stem cell technologies. Human embryonic stem cells, first isolated in 1998, appear promising as a source of cells that can be used to help the human body regenerate itself. Based on research performed in mice and rats, scientists are optimistic that stem cells may someday be implanted in human beings to regenerate cells or tissues, perhaps anywhere in the body, possibly to treat many conditions, ranging from diseases such as Parkinson's to tissue damage from heart attack.

Embryonic stem cells are derived from embryos, which are destroyed in the process. Some scientists are hopeful that they will be able to find stem cells in the patient's own body that they can isolate and culture, then return to the body as regenerative therapy. Others think that stem cells from embryos are the most promising for therapy. But if implanted in a patient, embryonic stem cells would probably be rejected by the patient's immune system. One way to avoid such rejection, some believe, is to use SCNT. An embryo would be created for the patient using the patient's own DNA. After a few days, the embryo would be destroyed. The stem cells taken from the embryo would be cultured and put into the patient's body, where they might take up the function of damaged cells and be integrated into the body without immune response.

Religious concerns about cloning

While many believe the potential benefits justify research in therapeutic cloning, some object on religious grounds. Many Roman Catholic and Orthodox Christians reject this whole line of research because it uses embryos as instruments of healing for another's benefit rather than respecting them as human lives in their own right. Others believe that if nonreproductive cloning is permitted, even to treat desperately ill patients, then it will become impossible to prevent reproductive cloning, and so they want to hold the line against all human uses of SCNT. A few Protestant and Jewish groups and scholars have given limited approval to nonreproductive cloning.

Outside the United States, most countries with research in this area reject reproductive cloning but permit cloning for research and therapy. In the United States, federal funding is not available as of 2002 for any research involving human embryos. Privately funded research, however, faces no legal limits, even for reproductive cloning. In 2001, one

U.S. corporate laboratory, Advanced Cell Technology, published its work, largely unsuccessful, to create human cloned embryos in order to extract stem cells. Some religious leaders object to this situation in which privately funded research is left unregulated.

When it comes to reproductive cloning, religious voices are nearly all agreed in their opposition, although they may give different reasons. Aside from a few isolated individuals, no one has offered a religious argument in support of reproductive cloning. All religious voices agree with the majority of scientists in their objection to cloning based on the medical risk that it might pose for the cloned person, who, even if born healthy, may experience developmental problems, including neurological difficulties, later in life. Until it is known that these risks are not significantly higher for the clone than for someone otherwise conceived, most scientists and ethicists agree that researchers have no right to attempt cloning.

Some religious scholars and organizations oppose cloning as incompatible with social justice. As an exotic form of medicine that benefits the rich, cloning should be opposed in favor of more basic health care and universal access to it.

Others oppose reproductive cloning because it goes against the nature of sexual reproduction, which has profound benefits for a species. Human beings are sexual beings, it is argued, and the necessity of sex for procreation is grounded in hundreds of millions of years of evolution and should not be lightly cast aside by technological innovation. Transcending the biological advantage of sexual procreation, some argue, are the moral and spiritual advantages of the unity of male and female in love, from which a new life emerges from the openness of being, far more than from the designs of will.

Some believe that cloning would confuse and probably subvert relationships between parents and their cloned children. If one person in a couple were the source of the clone's DNA, at a genetic level that parent would be a twin of the clone, not a parent. Whether biological confusion would amount to psychological or moral disorder is of course debatable, but any test might result in tragic consequences. Furthermore, cloning creates a child with nuclear DNA that, in some way at least, is already known. This nuclear DNA begins a new life, not with the usual uncertainties of sexual recombination but through the controls of technology. Many have said that the power to create a clone gives parents far too much power to define their children's genetic identity. Unlike standard reproductive medicine, even if combined in the future with technologies of genetic modification, cloning allows parents to specify that their child will have exactly the nuclear DNA found in the clone's original. This is assuredly not to say that parents may thereby select or control their child's personality or abilities, because persons are more than genes. But some fear that by its nature cloning moves too far in the direction of control and away from the unpredictability of ordinary procreation, so far in fact that a normal parent-child relationship cannot emerge in its proper course. To move in that direction at all is to risk subverting the virtues of parenting, such as unqualified acceptance.

Finally, some have held that cloning will place an unacceptable burden on the cloned child to fulfill the expectations that motivated their cloning in the first place. The fact that the parents may have some prior knowledge of how the clone's nuclear DNA was lived by the clone's original will lead the clone to think that the parents want a child with just these traits. One can imagine that clones will believe they are accepted and loved because they fulfill expectations and not because of their own unique and surprising identity.

In time, reproductive cloning may be widely accepted, much as in vitro fertilization has become accepted. But within religious communities, opposition to cloning is so strong that it is hard to imagine that religious people will ever accept it as a morally appropriate means of human procreation. Nevertheless, despite the strength of the objections, many recognize that human reproductive cloning will occur in time, and when it does the religious concern will shift from preventing cloning to affirming the full human dignity of the clone.

See also ANIMAL RIGHTS; BIOTECHNOLOGY; DNA; GENETIC ENGINEERING; REPRODUCTIVE TECHNOLOGY; STEM CELL RESEARCH

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CLOSED UNIVERSE

Within standard Big Bang cosmology essentially only three futures are available for the physical universe. The universe is either *open,* which means it will continue to expand at an ever increasing rate; or it is *flat,* which means it will only expand at a rate just sufficient to avoid collapse; or it is *closed,* which means the universe will expand to a maximum size and then collapse in upon itself. The total mass-density of the universe determines which scenario will be realized. At a critical mass-density, the universe is flat. If the mass-density is higher than the critical level, the universe is closed. Certain astronomical measurements suggest that the universe is very nearly flat, and yet estimates of mass-density are far below the critical level. This has led scientists to suspect that there is a great deal of matter as yet undetected. Whether there is enough of this unseen *dark matter* to cause the recollapse of the universe is a still unresolved question.

See also BIG BANG THEORY; BIG CRUNCH THEORY; COSMOLOGY, PHYSICAL ASPECTS

MARK WORTHING

COGNITIVE DEVELOPMENT

See EXPERIENCE, RELIGIOUS: COGNITIVE AND NEUROPHYSIOLOGICAL ASPECTS; NEUROSCIENCES; PSYCHOLOGY

COGNITIVE FLUIDITY

The term *cognitive fluidity* refers to the capacity of the modern human mind to combine different ways of thinking with stores of knowledge to arrive at original thoughts, which are often highly creative and rely on metaphor and analogy. As such, cognitive fluidity is a key element of the human imagination. The term has been principally used to contrast the mind of modern humans, especially those after 50,000 B.P. (before present), with those of archaic humans such as Neanderthals and *Homo erectus.* The latter appear to have had a mentality that was domain-specific in nature—a series of largely isolated cognitive domains for thinking about the social, material, and natural worlds. With the advent of modern humans the barriers between these domains appear to have been largely removed and hence cognition became more fluid.

See also EXPERIENCE, RELIGIOUS: COGNITIVE AND NEUROPHYSIOLOGICAL ASPECTS; EVOLUTION, HUMAN

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STEVEN MITHEN

COHERENTISM

Coherentism represents one of the most popular alternatives to foundationalism as a theory of belief justification. The easiest way to introduce the difference between them is to note their response to the problem of epistemic regress. Proponents of both sides agree that some beliefs are inferentially derived from or justified by their relation to other beliefs, which in turn are justified in relation to still other beliefs, and so on. A looming skepticism about the possibility of having *any* justified beliefs threatens if this regress cannot be stopped. The foundationalist halts the regress by identifying foundational (basic) beliefs that are justified not in relation to other beliefs, but by some other criterion, such as self-evidence, incorrigibility, or being evident to the senses. All other beliefs are founded upon these basic beliefs. The coherentist rejects this solution, arguing that the justification of every belief is dependent on its inferential relation to other beliefs and ultimately on its place in the whole web of a person's belief system. Foundationalists use the images of a linear chain or a pyramid to depict the structure of belief justification, while coherentists prefer the images of a web of belief or a raft with interlocking planks of divergent size and color.

It is important to understand the scope of any particular proposal for coherentism. If a comprehensive metaphysical theory of truth is the goal, coherentism may be linked to a radical idealist embracing of antirealism. Such a pure coherentism asserts that a belief is true if, and only if, it is a member of a consistent set of beliefs. In this extreme form, coherentism is open to several objections. For example, it appears to involve a viciously circular argument, in which beliefs mutually justify each other. It also allows for the possibility that two internally consistent sets of beliefs could both be true even if they contain contradictory beliefs between them. Finally, the radical coherentist position can lead to one despairing of ever justifying *any* belief, for how can one evaluate the inner logical consistency of *every* belief and its complex relation to the *whole* web of beliefs?

For these and other reasons, most contemporary coherence theories focus not on the metaphysical issue of truth but on the epistemological concern with knowledge and justification. Moderate forms of coherentism do not deny that sense experience plays a role in the formation of beliefs; they deny that this role is foundational. Beliefs must be justified in the context of the whole. For example, Nicholas Rescher's version of coherentism fits into his broader call for a "pragmatic idealism" that accounts for the role of experience and practice in the formation and justification of beliefs. Niels Henrik Gregersen has shown how a "contextual coherence" theory may provide a common framework of rationality for theology, science, and other modes of human inquiry. Those participants in the religion-science dialogue who prefer some form of critical realism over naïve realism or antirealism typically affirm coherence as a criterion of truth, but not as the definition of truth.

See also CRITICAL REALISM; EPISTEMOLOGY; EXPLANATION; FOUNDATIONALISM; REALISM; TRUTH, THEORIES OF

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F. LERON SHULTS

COMMON ANCESTOR

See EVOLUTION, BIOLOGICAL; EVOLUTION, HUMAN

COMPETITION

An important component of the neo-Darwinian theory of evolution, competition describes the theory that there is a struggle among organisms both of the same species (intraspecific) and between species (interspecific) for food, space, reproduction, and other requirements for existence. Through natural selection organisms develop adaptations to overcome or resist their own destruction in competition with the counter-adaptations developed by other organisms. These adaptations include physiological, chemical, and psychological traits. For example, organisms may evolve to become larger, more poisonous, or more aggressive. Such adaptations are not developed on the short timescale of individual lifetime but on the long evolutionary timescale of the species.

See also ADAPTATION; AGGRESSION; EVOLUTION; NEO-DARWINISM

ARN O. GYLDENHOLM

COMPLEMENTARITY

In his 1948/1949 Gifford lectures the Danish physicist Niels Bohr (1885–1962) suggested that theologians make more use of the Complementarity Principle. Articles in *Zygon: Journal of Religion and Science* from 1966 and elsewhere advocate and also oppose such use in regard to both theology and the relation of science and religion (Reich, 1994).

Bohr had introduced complementarity in 1927: "The very nature of the quantum theory thus forces us to regard the space-time co-ordination and the claim of causality, the union of which characterizes the classical theories, as complementary but exclusive features of the description" (Bohr, p. 115). Thus, complementarity here means to keep distinct what has traditionally been merged. In contrast, the complementarity of the particle-like and the wave-like behavior of light brings together "contradictory" models that traditionally are regarded as excluding each other.

A definition of *complementarity* that is applicable to both physics and theology reads as follows: Complementarity refers to the possibility that the same entity/phenomenon manifests itself in distinct, categorically different ways. All the differing manifestations need to be described and explained, and be part of an overarching theory of the entity/phenomenon, but not all occur in the same spatial, temporal, or situational context, respectively. Unfortunately, the meaning of the terms *complementarity* and *complementary* changes in everyday use (e.g., we are not opposed to or competing with each other but are complementary), as well as in communication theory (in contrast to symmetrical communication between same-level partners, complementary communication takes place between a superior and an inferior position), and in psychotherapy (in a complementary relation between client and psychotherapist the client's wishes regarding mutual love or hate and dominance or subjection are met; in an anti-complementary position none are met).

Given such a difficulty, why nevertheless search for complementarity in regard to science and religion? Because it opens up a logical possibility not covered by the traditional relationships (conflict, independence, dialogue, and integration) as defined by classical logic (Reich, 1996). That logic is binary: If the choice is between *A* and *B,* and *A* is correct, then *B* must necessarily be wrong. Genuine complementarity involves a trivalent logic, articulated by Hugo Bedau and Paul Oppenheimer in 1961 (compatible, incompatible, and noncompatible), which allows for a context-dependence of the respective explanatory powers. For instance, whereas both science and religion can contribute to the understanding and the significance of the origin and the evolution of the universe, science contributes more to an explanation of what actually happened, and religion to what it means for human living.

Complementarity as defined above involves ontology, epistemology, logic, and methodology. *Ontologically,* a meta-relation (entanglement as described in quantum physics by Werner Heisenberg's principle of indeterminacy) is posited between the class of contents/meanings pertaining to science and the class of contents/meanings pertaining to religion. For example, a person to whom God entrusts a mission (religion) also receives the capacity (science) to carry it through. The *epistemology* calls for ascertaining that the statements concerning science and religion are co-extensional, that is, they refer to the same entity/phenomenon. The logic has already been indicated. And finally, the *methodological* issue implies that science and religion/theology each use their own methods. From such a perspective one is led to conclude that complementarity cannot be looked for in science and religion *tout court,* but (if at all) in selected issues (Reich, 2002).

See also PHYSICS, QUANTUM; SCIENCE AND RELIGION, MODELS AND RELATIONS

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K. HELMUT REICH

COMPLEXITY

Whereas cosmology explores the boundaries of the very large, and quantum theory the nature of the very small, complexity theory aims to understand the emergence and development of orders at every level, including the medium size world. To the riddles of the macroscopic and the microscopic are added the puzzles of complex pattern formation in semistable dynamical systems known from everyday life.

Semistable systems are usually nonlinear, so small inputs may trigger dramatic changes. Examples are volcanos and tornados, embryologic and ecological evolution, traffic systems, and stock markets. These are not new areas of research, but the computerization of science since the 1970s has made possible new formalistic approaches to the study of dynamical systems. The question is hereby not so much "What are the constituents of nature (quarks, protons, electrons, etc.)?" but rather "How does nature work?"

Complexity theory, however, is not the name of a single theory comparable to, say, Albert Einstein's Theory of Relativity. There hardly exists one overarching "law of complexity" waiting to be discovered. Rather, complexity research is an umbrella term for a wide variety of studies on pattern formation, some more general, some arising under specific organizational conditions. The field builds on thermodynamics, information theory, cybernetics, evolutionary biology, economics, systems theory, and other disciplines. Since complexity research consistently crosses the boundaries between the inorganic and the organic, the natural and the cultural, it is likely to influence the science-religion dialogue significantly.

Algorithmic complexity

There is no consensus on a general definition of complexity. The complex is usually defined in contrast to the simple, but the distinction between simple and complex is a relative one. What is simple in one frame of reference may be complex in another. Walking downstairs, for example, is simple from the perspective of a healthy person, but physiologically it is highly complex. On the other hand, chaos theory shows that complex phenomena can be described by simple nonlinear equations.

An exact measure of *algorithmic complexity* has been available since the 1960s. In the Kolmogorov-Chaitin model, the complexity of a digital code consisting of 0s and 1s is measured by the length of the computer program needed to describe it. Even a long series of digits (e.g., 01010101010101010101 . . .) can be compressed into a compact description: "write 01 *x* times." By contrast, a complex code is a series without a discernable pattern; in the worst case, the series would simply need to be repeated by the computer program (e.g., 1001110010011000011 . . .). Such systems are by definition random. However, one can never know with certainty whether a series that one sees as random could be further compressed. This is an information-theoretical version of Gödel's incompleteness theorem discovered by Gregory Chaitin.

Similarly, C. H. Bennett suggested a measure for a structure's degree of complexity by referring to its *logical depth,* defined as the time needed (measured by the number of computational steps) for the shortest possible program to generate that structure. Both Chaitin and Bennett presuppose Claude Shannon's mathematical concept of information: The more disordered a message is, the higher is its informational content. While Chaitin's basic definition has the advantage of being extremely economic, Bennett's definition is capable of measuring the discrete operational steps involved in problem solutions. However, none of these formal definitions of complexity can distinguish organized complexity from pure randomness. The main interest of complexity studies, though, is to understand the self-organized complexity that arises in the creative zones between pure order and pure randomness.

Real-world complexity

To catch the idea of organized complexity, it may be useful to distinguish between descriptive, causal, and ontological aspects of complexity of natural and social systems. Systems that require different sorts of analyses have been called *descriptively complex* (Wimsatt, 1976). Fruit flies, for example, require a variety of descriptions, such as physical descriptions of their thermal conductivity, biochemical descriptions of their constitution, morphological descriptions of their anatomical organs, functional descriptions, and so on. This idea of descriptive complexity lends support to an explanatory pluralism, which emphasizes the need for different types of explanation at different levels.

Systems, however, can also be *pathway complex* while simple in structure if their causal effects are highly sensitive to environmental conditions. A hormone is a natural-kind entity with an easily specifiable molecular composition, but since the effects of the hormone depend on a variety of bodily constellations (which cannot be finitely determined), the causal trajectory of the hormone is complex. Systems theory and organicist proposals in biology have focused on this aspect of complexity.

The most difficult thing to define is *ontological complexity*. An element-based definition of complexity defines complexity by its large number of *variegated elements* (Bak, 1997, p. 5). This definition centers on the fact that many large-scale systems (mountains, geological plates, etc.) do not allow for an analytical approach of their microphysical states. A relation-based definition of complexity will rather focus on the *multiple couplings* of a system in relation to its environments (Luhmann, 1995, p. 23–28). The human brain with its high number of flexible neurons exemplifies that more possibilities of couplings exist than can be actualized in a life history. Since the capacity for complex interactions with the environment is usually increased by operational subsystems, organizational features can be added to the definition of complexity. An organization-based definition of complexity thus emphasizes the *hierarchical structure* of interacting levels. Analogously, a performance-based definition focuses on the *capacity for self-organizing activity*. Systems are thus ontologically complex if they (1) consist of many variegated elements (in terms of sizes and types), (2) have a high capacity for relating to themselves and their environments, (3) are highly organized in subsystems, multilevel structures, and internal programs, and (4) can perform self-organized activities by flexible couplings to the environment. On this scheme it is possible to evaluate different aspects of complexity. A volcano will be more complex than an amoeba on (1) elements and perhaps on (2) relations, but far less complex on the score of (3) hierarchical order and (4) self-organizing activity.

On this scheme, the complex can also be distinguished from the merely complicated (Cilliers, 1998). Even "primitive" natural entities such as genes may be ontologically more complex than sophisticated artificial systems such as airplanes. A Boeing 747 jet consists of highly specified elements, related to one another in predescribed ways, and there exists a clear recipe for how to assemble the elements into a unified system, which again has a predesigned purpose: being able to take off, fly, and land safely. The Boeing is a highly complicated machine but not terribly complex. In this sense, the complex is more than the simple but also more than the complicated.

Noncomputational complexity

Complexity studies fall into two main families of research, one more conceptual (organicism, emergentism, and systems theory) and another more formalistic (information theory, cybernetics, and computational complexity). Both types of research continue to interact in understanding complex phenomena. While a conceptual preunderstanding of complex phenomena guides the construction of computational models, these will afterwards have to be tested on real-world situations.

Complexity studies did not start with computers. The idea that the whole is more than the sum of the parts goes back to Plato's notion of divine providence (*Laws* 903 B-C), and in *Critique of Judgment* (1790) Immanuel Kant describes a naturalized version of the same idea of self-adjustment: "parts bind themselves mutually into the unity of a whole in such a way that they are mutually cause and effect of one another"(B 292).

Embryologists from Karl Ernst von Baer and Hans Spemann up to C. H. Waddington embraced *organicism* as the middle course between vitalism and reductionism. In organicism a materialist ontology ("there exists nothing but matter") was combined with the observation that new properties are causally effective within higher-order wholes. Molecules are not semipermeable, but cell membranes are, and without this capacity organisms cannot survive. In the 1920s writers such as C. Lloyd Morgan, C. D. Broad, and Samuel Alexander developed organicism from an empirical research program into a metaphysical program of *emergent evolutionism.* The point here was that in the course of evolution higher-order levels are formed in which new properties emerge. Whereas the solidity of a table is a mere "resultant" of solid state physics, the evolution of life is ripe with "emergent" properties (for example, metabolism) that require new forms of description and eventually will have real causal feedback effects on the physical system (the atmosphere) that nourished life in the first place.

After World War II the *general systems theory* combined organicistic intuitions with cybernetics. Ludwig von Bertalanffy replaced the traditional whole/part difference by the difference between systems and environments. Systems are constitutionally open for environmental inputs and are bound to develop beyond equilibrium under selective pressures. Thereby systems theory established itself as a theory combining thermodynamics and evolutionary theory. Systems are structures of dynamic relations, not frozen objects.

In the 1960s Heinz von Foerster and others introduced the theory of self-referential systems according to which all systems relate to their environments by relating to their own internal codes or programs. Brains don't respond to cats in the world, but only to the internal firings of its neurons within the brain. "Click, click is the vocabulary of neural language" (von Foerster). In this perspective, closure is the precondition of openness, not its preclusion. In this vein, biologists Francisco J. Varela and Humberto Maturana developed a constructionist research program of *autopoietic* (self-productive) systems. The sociologist Niklas Luhmann has further emphasized how systems proceed by self-differentiation and can no longer be analyzed by reference to global physical features of the world-as-a-whole. In this perspective, each system needs to reduce, by its own internal operations, the complexities produced by other systems. Different systems (for example, biological, social, psychic) operate with different codes (energy, communication, consciousness), and even though they coevolve they cannot communicate with one another on neutral ground. The fleeting experience of consciousness, for example, remains coupled to physiological processes and to social communication, yet has its own irreducible life.

Computational complexity

Computational complexity presupposes the idea of algorithmic compression and embodies the spirit of cybernetics. The dictum of Norbert Wiener that "Cybernetics is nothing if it is not mathematical" (1990, p. 88) could also be said of computational complexity.

The field of cybernetics was developed after World War II by John von Neumann, Ross Ashby, Norbert Wiener, and others. Central to cybernetics is the concept of *automata,* defined as machines open for information input but leading to an output modified by an internal program. In cybernetic learning machines, the output functions are reintroduced into the input function, so that the internal program can be tested via trial and error processes. However, the measure for success or failure is still fixed by preset criteria.

The cybernetic automata were the direct precursors of *cellular automata,* used in the artificial life models designed by John Conway and Chris Langton in the 1970s. Cellular automata use individual based modeling: "Organisms" are placed in cubic cells in a two-dimensional grid, and their "actions" (die or divide) are specified by the number of living cells in their immediate neighborhood. In this way, the positive feedback of breeding can be modeled as well as the negative feedback of competition. The result is self-reproducing loops generated by very simple rules.

With the establishment of the Santa Fe Institute in New Mexico in 1984 a multidisciplinary center for computational complexity was formed. Physicist Murray Gell-Mann, computer scientist John Holland, and others introduced the idea of *complex adaptive systems.* As opposed to simple adaptation (as in a thermostat), there are no preset goals for complex adaptive systems. Like cellular automata, complex adaptive systems are individually modeled systems, but complex adaptive systems also involve "cognition." Complex adaptive systems are able to identify perceived regularities and to compress regular inputs into various schemata. Unlike cybernetic learning machines, there may be several different schemata competing simultaneously, thus simulating cognitive selection processes. In this manner self-adaptation coevolves with adaptation beyond a preset design. Whereas Gell-Mann uses complex adaptive systems as a general concept, Holland uses the term only about interacting individual agents. Complex adaptive systems agents thus proceed by a limited set of interaction rules, governed by simple stimulus-response mechanisms such as (1) tags (e.g., if something big, then flee; if something small, then approach), (2) internal models (or schemata), and (3) rules for connecting building blocks to one another (e.g., eyes and mouth to facial recognition). The result of these local mechanisms, however, is the emergence of global properties such as nonlinearity, flow, diversity, and recognition.

Insofar as complex patterns are generated by simple mechanisms, computational complexity can be seen as a reductionist research paradigm; in contradistinction to physical reductionism, however, the reduction is to interaction rules, not to physical entities. But insofar as higher-level systems can be shown to exert a "downwards" feedback influence on lower-level interaction-rules, computational complexity may also count as an antireductionist research program. The issues of reductionism versus antireductionism, bottom-up versus top-down causality, are still debated within the computational complexity community. But anyway, it is information and not physics that matters.

Computational complexity and real-world complexity

The spirit of computational complexity is not to collect empirical evidence and "reflect" reality, but to "generate" reality and explore virtual worlds of possibility. Computational complexity is nonetheless empirically motivated and aims to understand real-world complexity by computer modeling. The aspiration is to uncover deep mathematical structures common to virtual worlds and real-world dynamical systems.

The mathematical chaos theory is an example of a computer-generated science that has succeeded in explaining many dynamical patterns in nature. Yet the relation between chaos theory and computational complexity is disputed. While chaotic systems (in the technical sense) are extremely sensitive to the initial conditions, complex systems are more robust (that is, they can start from different conditions and still end up in almost the same states). Accordingly, chaos theory can predict the immediate next states but not long-term developments, whereas complex systems can reliably describe long-term prospects but cannot predict the immediate following steps. Moreover, chaos systems do not display the kind of evolutionary ascent and learning characteristic of complex adaptive systems, but oscillate or bifurcate endlessly. It therefore seems fair to say that chaos theory is only a small pane in the much larger window of complexity studies. Chaos, in the colloquial sense of disorder, is everywhere in complex systems (and so are fractals and strange attractors), but the equations of chaos in the technical sense (the specific Lyapunov-exponent, etc.) cannot explain self-organized complexity.

There are also connections between thermodynamics and complexity theory. Beginning in the 1960s, the chemist Ilya Prigogine studied the so-called dissipative structures that arise spontaneously in systems dissipated by energy. While classical thermodynamics described isolated systems where nonhomogeneities tend to even out over time, Prigogine studied nonequilibrium processes of "order out of chaos" (*chaos* in the nontechnical sense). Famous examples are the convection patterns of Bénards cells formed spontaneously under heating or the beautiful chemical clocks of the Belousov-Zhabotinski reaction. While Ludwig Boltzmann's law of entropy from 1865 still holds for the universe as a whole, the formation of local orders is produced by nonequilibrium thermodynamics. The averaging laws of statistical mechanics are not contradicted, but they simply do not explain the specific trajectories that develop beyond thermodynamical equilibrium.

In the wake of Prigogine, a new search for the thermodynamical basis of evolution began (Wicken, 1987). The bifurcation diagrams of Prigogine showed amazing similarities to evolutionary trees. Reaching back to the seminal work of D'Arcy Wentworth Thompson in *On Growth and Form* (1916), many began to think that the interplay of selection and mutation is not self-sufficient for explaining the evolutionary tendency towards complexification. Evolution may be driven by gene selection *and* prebiotic laws of physical economy.

Since the 1970s, theoretical biologist Stuart Kauffmann has constructed computational models of self-organizing principles at many levels. Motivated by the almost ubiquitous tendency of chemical systems to produce autocatalytic systems, Kauffman theorizes that life may have emerged quite suddenly through phase transitions where chemical reactions function as catalysts for one another far below the threshold of the RNA-DNA cyclus. Kauffman uses a similar model for simulating the empirical findings of Francois Jacob and Jacques Monod, who showed that genes switch on and off depending on the network in which they are situated. In the simplest model of Boolean networks, each "gene" is coupled randomly to two other genes with only two possible states, on or off (states that are determined by the states of the two other genes). Running this small system with only three genes and two activities recurrently (and later with much larger networks), Kauffman was able to show that the number of state cycles (attractors) increase with the number of genes. Moreover, their relation is constant so that the number of state cycles is roughly the square root of the number of genes, and Kauffman points out in *The Origins of Order* (1993) that in real-world species one finds roughly the same relation between the number of genes and the number of cell types in a given species. Thus, agents in coupled systems seem to tune themselves to the optimal number of couplings with other agents. In addition, when investigating fitness landscapes of interacting species at the ecological level, Kauffman finds the principle of "order for free." Evolutionary innovations tend to happen "at the edge of chaos," between the strategy of evolutionarily stable orders and the strategy of the constant evolutionary arms race. In *Investigations* (2000), Kauffman pursues a search for laws by which the biosphere is coconstructed by "autonomous agents" who are able run up against the stream of entropy. Kauffman hereby acknowledges the impossibility of prestating finitely what will come to be within the vast configuration space of the biosphere.

The theory of *self-organized criticality* formulated by Per Bak and his colleagues starts in empirically confirmed regularities (such as the Gutenberg-Richter law of earthquakes). Many systems show slow variation over long periods, rare catastrophic activities over short time, and some critical phases in between. The building up of sand piles shows these phase transitions, but so do earthquakes, extinction rates, and light from quasars. Bak's point is that self-organized criticality systems are self-organizing, since they (1) are robust and do not depend on specific initial conditions, (2) emerge spontaneously over time (with no external designer), and (3) are governed by the same mathematical principles in stationary, critical, and catastrophic states. Bak has made both real-world experiments and simplified computer-models of self-organized criticality systems, but he believes that self-organized criticality is only a first approximation of stronger explanations of nature's tendency to build up balances between order and disorder.

Relevance for the science-religion discussion. While organicist programs of noncomputational complexity have played a major role in the science-religion dialogue since the seminal works of Ian Barbour, Arthur Peacocke, and others, the relevance of computational complexity for theology largely remains to be explored. The following issues are therefore to be taken more as pointers than as conclusions:

(1) The sciences of complexity study pattern formations in the midst of the world rather than in a hidden world beyond imagination. The features of organized complexity resonate with the experiences of being-part-of-a-whole, experiences that since Friedrich Schleiermacher's *On Religion* (1799) have been taken to be essential to religious intuition.

(2) While presupposing a robust naturalism, complexity theory suggests that "information" is as seminal to nature as are the substance and energy aspects of matter. Complexity theory may thus give further impetus

to the dematerialization of the scientific idea of matter in the wake of relativity theory.

(3) By focusing on relations and interactions rather than on particular objects, complexity theory supports a shift in worldview from a mechanical clockwork view of the world to an emergentist view of the world as an interconnected network, where flows of information take precedence over localized entities. Complexity theory also offers a road for understanding the evolution of coevolution. By balancing the principle of individual selection by principles of self-organization, the focus on individual genes is supplemented by the importance of interconnected living organisms, a view closer to ethical and religious sentiments than the inherited view of the omnipotence of selection.

(4) Even though natural evils (from earthquakes to selection) remain a challenge to religions that presuppose a loving almighty God, the costs of evolutionary creativity are now being placed in a wider framework of evolution. If the same underlying dynamics of self-organized criticality produce both stability, criticality, and catastrophes, and the constructive aspects of nature cannot exist without the destructive aspects, a theodicy of natural evils may be facilitated.

(5) The idea of complex adaptive systems gives biological learning and human culture (including science, ethics, and religion) a pivotal role in the understanding of what nature is, and what makes human and animal life grow and flourish. In addition, since complexity theory consistently crosses the boundaries between physics, biology, and the cultural sciences, theologians and human scientists may be prompted to rethink human culture (including religion) in terms of the creative interactions between the inorganic, the organic, and the cultural.

(6) From an external scientific perspective, computational complexity may be used to explain a variety of religious phenomena that arise at the critical interface between adaptation and self-adaptation, such as the interaction between religious groups, individual conversion experiences, and so on. The first computer models in this area have already been completed.

(7) From an internal religious perspective, complexity theory offers religious thought a new set of thought models and metaphors, which (when adopted) can stimulate the heuristics of theology when complex phenomena are redescribed from the perspective of religious symbolics. Self-organization, coupled networks, and adaptation by self-adaption are candidates for such religious self-interpretation. The principles of complexity are in particular consonant with the idea that a divine Logos is creatively at work in the pattern formations of nature and drives nature towards further complexification.

(8) The computational complexity idea of self-organization is a challenge to the Enlightenment idea of a divine designer of all natural processes. Self-organization is also a challenge to the creationist Intelligent Design movement, which gives priority to the idea of "original creation" and tends to perceive novelties as perversions of pre-established designs. However, self-organizational processes never happen from scratch, but always presuppose a framework of laws and natural tendencies that could well be said to be "designed" by God. While a design of specific evolutionary outcomes is obsolete in light of self-organized complexity, the coordination of laws leading towards self-organization and coevolution may be explained by a divine metadesign.

(9) Since emergence takes place in the merging of coupled systems, theology may escape the alternative between an interventionist God, who acts by breaking natural laws, and a God who only sustains the laws of nature uniformly over time. In higher-organized systems, new informational pathways are continuously tried out in adventurelike processes. If the local interaction rules and the overall probability patterns are constantly changed over time, the actual pathways of large-scale coupled systems are not reducible to the general laws of physics. Special divine interaction with the evolving world can thus no longer be said to "break laws" in an interventionist manner, since there are no fixed laws to break in coupled systems.

(10) The seminal idea of self-organization may help overcome the idea that God and nature are contraries, so that God is powerless, if nature is powerful, and vice versa. A more adequate view may be to understand God as the creator who continuously hands over creativity to nature so that natural processes are the signs of a divine self-divestment into the very heart of nature's creativity. On this view, God is at work "in, with, and under" natural and social processes, and self-organization takes place within a world already created and continuously gifted by God.

See also AUTOMATA, CELLULAR; AUTOPOIESIS; CHAOS THEORY; CYBERNETICS; EMERGENCE; INFORMATION THEORY; INTELLIGENT DESIGN; SYSTEMS THEORY; THERMODYNAMICS, SECOND LAW OF

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COMPUTER

See INFORMATION TECHNOLOGY

CONFLICT

See MODELS; SCIENCE AND RELIGION, MODELS AND RELATIONS; SCIENCE AND RELIGION, METHODOLOGIES

CONFUCIANISM

See CHINESE RELIGIONS, CONFUCIANISM AND SCIENCE IN CHINA

CONSCIOUSNESS STUDIES

Consciousness studies is a new, rapidly evolving, highly interdisciplinary field that includes psychology, philosophy, physics, sociology, religion, dynamic systems, mathematics, computer science, neuroscience, art, biology, cognitive science, anthropology, and linguistics. In the early 1990s, most scientists considered consciousness taboo, but by the early 2000s many considered it the most important unsolved problem in science. Consciousness is also a key issue in the ongoing dialogue between science and religion. The dominant view of consciousness in the hard sciences is materialist and reductionist. This view has had important successes, but it also faces important unresolved problems. For example, biologist Francis Crick to wrote of his audience, "You're nothing but a pack of neurons" in parody of Lewis Carroll. But most people, including those in consciousness studies, and even in neuroscience, think there is much more to human life than can be seen at the level of neurons.

Notions of consciousness are important in many religions. The term *God consciousness* figures in the Protestant theology of Friedrich Schleiermacher and his followers, and *Christ consciousness* is used in some Christian and New Age religions, sometimes in a dubious way. *Cosmic consciousness* is important in Hinduism, especially Vedanta, and *pure consciousness* is important in the Buddhist school called *Dzogchen* in Tibetan and *Maha Ati* or *Mahasandhi* in Sanskrit. Consciousness is also a common theme in the Tantric traditions. Reports of meditation experience are taken more seriously in consciousness studies than in the hard sciences, where researchers often dismiss such data as mere subjective experience. On the other hand, due to close connections with various religions, some writers on consciousness have hidden (or not so hidden) agendas, so that caution is called for when approaching some literature on consciousness studies.

In general, the hard sciences tend to reduce consciousness to the material, while religions are more concerned with mental or spiritual aspects. This reflects the heritage of mind-body separation associated with the seventeenth-century French philosopher René Descartes. Although there is no single dominant view of consciousness, nor even any generally accepted definition, consciousness studies has made significant progress.

Shape of the field

At of the turn of the twenty-first century, consciousness studies has a professional society, the Association for the Scientific Study of Consciousness (ASSC); one highly interdisciplinary journal, the *Journal of Consciousness Studies* (*JCS*); and three journals devoted mainly to scientific and philosophical studies, *Consciousness and Cognition, Consciousness and Emotion,* and *Psyche,* the latter being an electronic journal. *JCS* sponsors a popular online discussion group. Many other journals, such as *Behavioral and Brain Sciences* and *Mind,* publish articles on consciousness. The University of Arizona in Tucson hosts a research center on consciousness studies and has organized an important biannual conference series since 1994. *Consciousness and Cognition* and *Psyche* are official journals of ASSC, which also organizes a biannual conference. Well known universities offering courses on consciousness include New York University in New York City, Bryn Mawr College in Pennsylvania, Vanderbilt University in Nashville, the University of Colorado in Boulder, the University of Virginia in Charlottesville, and the University of Arizona in Tuscon. Advanced degrees in consciousness studies are offered by the University of Skoevde in Sweden, Greenwich University in Australia, and Birla Institute of Technology and Science in India, among others. John F. Kennedy University in Orinda, California, has a Department of Consciousness Studies, and Brunel University in London offers an MSc degree in Cognition and Consciousness. In addition, there are many specialized conferences, and the emergence of the specialized journal *Consciousness and Emotion* in 2000 is a sign that the field is maturing.

Issues, paradigms, and results

It is difficult to single out any small set of key issues, not only because of the rapid growth of the field, but also because each of its many paradigms defines different sets of issues as central, secondary, marginal, and meaningless. Nonetheless, the following are some issues, paradigms, and results that seem most important in the literature.

The most obvious issue is how to study consciousness. Despite the fact that the advocates of various approaches are in constant, sometimes acrimonious, dialogue, no approach has been completely discredited, except perhaps that of mediums, spiritualists, and the like. This is why the editorial policy of *JCS* calls for a wide diversity of views, and aims to promote dialogue among them, and why the Tucson conference follows a similarly liberal policy. As the distinguished philosopher John Searle famously noted: At our present state of the investigation of consciousness, we don't know how it works, and we need to try all kinds of different ideas. Nevertheless, journals and conferences devoted to specific aspects of consciousness studies can be valuable.

Mind and body relation. The relation between mind and body is another major issue. Are mind and body the same kind of thing, or are they different? Or perhaps the same thing but differently perceived? Monism says there is just one kind of thing, and material monism (also called physicalism) says that all things are material, while mental monism (also called idealism) says that all things are mental. The dualism associated with Descartes says that both material and mental things exist. There are many variants of these and many other positions. Philosophical interpretations of consciousness wedded to reductionist scientific approaches like neuroscience and experimental psychology tend to be material monist. The philosopher David Chalmers is a kind of dualist, who argues that in addition to matter, information is a second fundamental world constituent. The philosopher Paul Churchland is an "eliminative materialist" monist, who argues that there is really no such thing as consciousness. Searle is an "emergent materialist" monist, who argues that consciousness is a distinct level of phenomena, emerging out of lower level brain activity, which only exists when it is experienced.

It is difficult to find adherents of either dualism or mental monism among eminent scientists. The most prominent acception is the Nobel Prize winning physiologist John Eccles, who advocated a form of interaction dualism similar to that of Descartes. Bishop George Berkeley (1685–1753) was the last major Western philosopher to advocate mental monism. On the other hand, dualism is the most common position in Christianity, as is mental monism in South and East Asian religions. For example, the Buddhist school of Yogacara posits a form of mental monism and is considered foundational for Buddhist Tantra. Traditions in Hinduism and Taoism can also be considered mental monist.

In "Conversations with Zombies," Todd Moddy investigates an amusing development in the debate among these positions: The possibility (or impossibility) of "philosophical zombies," creatures having exactly the same physical structure as ordinary humans, but without consciousness. Metaphysical debates about basic world substances seem to contribute little to the understanding of consciousness. Reconceptualizing the two main views as the scientific and phenomenological methods, instead of reifying them as world substances, leads to more fruitful projects such as the refinement of these views and their combination in productive syntheses.

Cognitivism. A once dominant approach in decline well before the end of the twentieth century is that of early cognitive science and artificial intelligence, often called cognitivism. This paradigm's model of the mind identifies cognition with computation, and the brain as the hardware on which it runs. The lineage of cognitivism traces back to pioneering work of Norbert Wiener on cybernetics, and to the Macy Conferences, organized since 1947 by anthropologists Margaret Mead, Gregory Bateson, and others, introducing systems theory to a key cross-disciplinary group. But cognitivists often ignore these antecedents and instead cite linguist Noam Chomsky's scalding review of psychologist B. F. Skinner's 1957 book *Verbal Behavior*. Skinner advocated behaviorism, a psychological theory that tried to ignore internal mental states. Chomsky argued that such states are needed to process even simple syntax. Another seminal cognitivist work, *Plans and the Structure of Behavior* (1960) by George Miller, Eugene Galanter, and Karl Pribram, proposed that human plans have the same structure as a certain simple kind of computer program. This tradition generally relies on formal logical representations of knowledge about the world. The cognitivist paradigm flourished beginning in the 1960s, partly fueled by large military funding for artificial intelligence.

Cognitivism has been much criticized. A famous early attack was Searle's Chinese room argument, which challenged the idea that a program running on a machine could be conscious. Another serious challenge came from James Gibson's work on affordances, showing that many cognitive tasks are greatly simplified by relying on information already in the world, instead of complex internal representations. Work in cognitive linguistics, as represented by George Lakoff and Mark Johnson's *Metaphors We Live By* (1980), showed that many basic metaphors rely on innate sensory-motor schemas. The sociologist Lucy Suchman showed that human plans as actually used can have structure and execution very different from that postulated by Miller, Galanter, and Pribram.

Biologist Francisco Varela, philosopher Evan Thompson, and psychologist Eleanor Rosch (all Buddhists) used empirical evidence in *The Embodied Mind* (1991) to argue that cognition is necessarily embodied, rather than disembodied like a computer. They also drew on Buddhist philosophy to show how cognition is possible without a "self." This book is a brilliant synthesis of cognitive science and religion. Rodney Brooks of the Massachusetts Institute of Technology has built robots which demonstrate that logical representation of knowledge is not necessary for the embodied action of locomotion. The anthropologist Edwin Hutchins argued that real world cognition is often distributed over individuals, rather than localized in a single individual, one example being navigation on large ships. There is also a growing body of work, such as that by Jaak Panskeep, showing that cognition is not entirely rational and disembodied because emotion plays a central role. All these developments are deeply inconsistent with cognitivism, though the significance of the work done before 1900 was not then generally appreciated.

Phenomenology. Phenomenology is an area of philosophy with important implications for consciousness. Phenomenology seeks to ground everything in the actual experience of human beings; in other words it takes a "first person" experiential perspective, rather than "third person" scientific perspective. Important exponents include Edmund Husserl, Martin Heidegger, and Maurice Merleau-Ponty. Heidegger considered implications of embodiment, including finitude and temporality, noting that humans are historical beings, bounded in time, space, and ability. Many of these themes also appear in the anti-cognitivist movement. Another such theme, with origins in Heidegger and especially Merleau-Ponty, but developed by Hubert Dreyfus, is the phenomenological critique of representation, which draws on human experience with routine activities to argue that representations are not necessary for embodied action. The work of Merleau-Ponty predates Gibson and Brooks, but is non-empirical, while Dreyfus makes compelling use of work by Walter Freeman connecting brain dynamics with chaos theory.

Neuroscience. The decline of cognitivism has inspired a return to naturalism, the study of cognition as it actually occurs in living human beings and, in particular, a shift towards neuroscience and evolutionary biology. Neuro-reductionism is perhaps the dominant position at the beginning of the twenty-first century. Certainly one can find neural correlates of consciousness or patterns of neural activity that correlate with various conscious experiences, such as visual perception. But it remains unclear whether such correlates can ever explain the nature of consciousness. A narrower version of this challenge is to explicate *qualia,* which are the qualitative aspects of consciousness, such as "how it feels" when one is angry or when one sees the blue of the sky. David Chalmers has introduced an influential distinction between the "easy" and the "hard" problems of consciousness studies:

> The easy problems are those of finding neural mechanisms and explaining cognitive functions: the ability to discriminate and categorize environmental stimuli, the capacity to verbally report mental states, the difference between waking and sleeping. The hard problem is that of *experience*: why does all this processing give rise to an experienced inner life at all? While progress is being made on the easy problems, the hard problem remains perplexing. (p. 200)

One approach to bridging this gap is to postulate that consciousness is some form of emergent activity of the brain. A familiar example of an emergent property is the liquidity of water, which arises from a sufficiently large collection of water molecules at an appropriate temperature.

Another problem facing neuroscience is the *binding problem,* which is to determine how the brain integrates sensory input from different times and/or different modalities to create a coherent seeming whole. Few doubt that this problem is solvable within the neuro-reductionist paradigm, though the complete answer will likely be complex. Neuro-reductionism has been especially successful in studying perception and this success has inspired interesting speculations on consciousness. In *Art and the Brain* (2000), Joseph Goguen demonstrates the intriguing possibility that such research can help people understand art. Critics have complained, however, that the cultural aspects of art get short changed by neuro-reductionist analyses.

Another problem is to determine the modularity and plasticity of the brain and the mind. Studies have found brain locations associated with many mental functions, but other functions have been shown to be non-local. Recent work has demonstrated physical brain change associated with learning, even relatively late in life. There is strong support for the modularity of many unconscious perceptual processes, and for the non-modularity of many higher level conscious processes. Whether there is a *language module,* as claimed by Noam Chomsky, remains contentious. A growing consensus is against his anti-evolutionary view of the origin of language, in which he claims that "there is no substance to the view that human language is simply a more complex instance of something to be found elsewhere is the animal world" (1972, p. 70).

On the interface between neurophysiology and computer science is the issue of modeling neurons, networks of neurons, and ultimately, brains. In 1943 Warren McCullough and Walter Pitts introduced the first such model, in which neurons were either "on" or "off," firing or not firing. These neurons are similar to the logic gates of computers, but are far simpler than real neurons. Some key ideas introduced by psychologist Donald Hebb include the following: connections between neurons become tighter the more they are used; neurons act in groups called *cell assemblies*; and cell assemblies are the basis of short term memory, but not long term memory. Although these only a rough approximation to the complex functioning of real neurons (involving numerous chemical reactions), they inspired a new generation of models having important engineering applications, such as character recognition. But because of its approximate character, many researchers prefer to call their work *parallel distributed processing* or *connectionism,* rather than neural net modeling.

Meanwhile, experimental neuroscience has uncovered even more complexities, some of which may have profound implications for consciousness. Benjamin Libet found that voluntary acts are preceded by a readiness potential (a gradual negative shift in electrical potential, as recorded at the scalp) about 550 milliseconds before the action occurs, and about 200 milliseconds before subjects recorded a conscious intent to act. This research has generated some controversy, including arguments that it implies that consciousness is constructed well after the fact, and even that consciousness may be unimportant. Mirror neurons are another significant discovery. The Italian neurophysiologist Giacomma Rizolatti found that certain cells in monkey frontal lobes respond to specific actions, not only in the subject, but also when the subject observes another monkey perform that same action. It has been suggested that this phenomenon may help explain many puzzles, such as how people learn by imitation, or how they can put themselves in the place of another in order to outsmart them should be added to this list the capacity for compassion, the ability to empathize with others. Blind sight is another intriguing phenomenon, in which, for example, a subject reports inability to see an object, but can still guess its location with reasonable accuracy (Weiskrantz). This dissociation between perception and awareness raises questions about the relation between conscious and unconscious processes.

Quantum mechanics. Physicists have not been shy to speculate about the relevance of quantum mechanics to consciousness. This is unsurprising, since the two have long been linked by the "Copenhagen interpretation" of Niels Bohr (and as augmented by John von Neumann), which says that, when an experiment is performed, the consciousness of an observer is needed to "collapse" the state probability distribution associated to the wave function down to a single state. This was always controversial, but it remains respectable despite difficulties with quantum coherence. Physicist Roger Penrose, instead of explaining quantum mechanics with consciousness, seeks to explain consciousness with quantum mechanics. The results seem stimulating but disappointing because his major conclusion is that some as yet nonexistent physics (quantum gravity) is needed. Penrose also argues against cognitivism, though he relies on a Platonist philosophy of mathematics, in which abstract mathematical objects are as real as chairs, trees, and people. David Bohm is another physicist who has written about consciousness, particularly in relation to the non-sectarian spiritual teachings of Jiddu Krishnamurthy, which helped inspire novel versions of quantum mechanics having philosophical interpretations that involve information and consciousness.

God and consciousness. Attempts to prove the objective existence of God have a long and important history. Although every such attempt has failed, the dialectic of refutation and refinement has been surprisingly productive, especially in certain areas of formal logic. This is relevant to consciousness studies because if the traditional Christian God exists in a separate realm of spirit, intervening in the material world, then dualism is true, the mind-body problem is solved, and the hard problem of consciousness takes on a very different, more theological, character. Using modern tools from information theory, William Dembski has attempted a sophisticated revival of an ancient proof that an intelligent designer is needed to account for the regularities of the universe. Dembski's work has been greeted with skepticism, and even hostility, by the scientific community, in part because his an anti-Darwinism has been embraced by fundamentalist Christians, who advocate teaching creation science in the schools, and in part because of technical difficulties in his argument.

A very different God is discussed by Anthony Freeman, motivated by the idea of treating conscious states as emergent properties of brain states. Freeman views both God and the soul as emergent from individuals and communities, claiming that this view is neutral between dualism and reductive materialist monism. He draws on work of Schleiermacher, Searle, and recent advocates of a more social approach to biology, such as Raphael Nuñez. A simpler approach than that of Dembski or Freeman may be to avoid ontological questions by placing the existence of God in the category of first person experience, rather than third person fact; one often sees this in contemporary expositions of the Buddhist tantra.

Emerging trends

Biologists are applying sociobiology and evolution to consciousness, though most results are rather speculative—e.g., work about the possible co-evolution of language and consciousness. Some less speculative work is being done in ethics, as illustrated in a brilliant series of essays edited by Leonard Katz and published in 2000 in JCS.

There have been proposals to merge phenomenology and science (such as the neurophenomenology of Francisco Varela), and even proposals to reformulate science based on phenomenology. More such proposals can be expected, in part because experience provides phenomena that demand explanation, including the following aspects of consciousness: it is ineffable, open, fluid, nonlocal, temporally thick, and involves qualia and a sense of self. Can it be mere coincidence that similar properties are often attributed to God? Reports from experienced meditators suggest additional phenomena, such as certain states of consciousness in which there are no thoughts. Moreover, the emphasis on time in phenomenology resonates well with many issues and results in neuroscience.

Another approach, sometimes called *second person,* is to relate consciousness to society rather than to individuals. One example is the cultural-historical approach, in the tradition of philosophers Giambattista Vico, Wilhelm Dilthey (who built on Schleiermacher), and John Stuart Mill, and of the Russian activity theory of Lev Vygotsky, Alexander Luria, and others. The second person approach is also related to distributed cognition and to the actor-network theory of Bruno Latour and others. The area of sociology called ethnomethodology also seems promising. The hope of second person approaches is to transcend the problematic relationship between mind and body; debates here often parallel those in consciousness studies and emerging syntheses like the cultural psychology of Michael Cole could likely illuminate several issues in consciousness.

Moving away from the social sciences, PET and fMRI techniques will certainly continue to yield provocative results about brain function. Also, dynamical systems and chaos theories seem promising. Perhaps semiotics can also make a contribution. Ideas from ecology, feminism, and literature should also play a role. Definitely, there will be more fermentation, discussion, and progress.

See also ARTIFICIAL INTELLIGENCE; BEHAVIORISM; COPENHAGEN INTERPRETATION; EMERGENCE; EXPERIENCE, RELIGIOUS: COGNITIVE AND NEUROPHYSIOLOGICAL ASPECTS; EXPERIENCE, RELIGIOUS: PHILOSOPHICAL ASPECTS; MIND-BODY THEORIES; MIND-BRAIN INTERACTION; MONISM; NEUROSCIENCES; PHYSICALISM, REDUCTIVE AND NONREDUCTIVE; PHYSICS, QUANTUM

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JOSEPH A. GOGUEN

CONSONANCE

See MODELS; SCIENCE AND RELIGION, METHODOLOGIES; SCIENCE AND RELIGION, MODELS AND RELATIONS

CONSTRUCTIVISM

The term *constructivism* denotes a heterogeneous set of theoretical approaches currently stemming from areas so diverse as biology, neurophysiology, philosophy, sociology, cybernetics, cognitive psychology, rhetoric, and literary studies. In all their variety they share the basic idea that knowledge cannot be based on some kind of correspondence to or representation of actual reality but only on the active cognitive constructions or cognitive operations of an observer. Any possible "objects" of experience and knowledge are embedded in cognitive and social processes.

Historically speaking the roots of constructivism begin in ancient skeptical philosophy, pass through the enlightenment philosophy of Immanuel Kant (1724–1804), the philosophy of language, and eventually to pragmatism. The most recent versions are *radical constructivism* and *operational constructivism,* where the term *construction* refers (1) to the construction of reality, (2) the construction of knowledge, and (3) the construction of tools and skills for human cognition.

Important impulses for radical constructivism were provided by Heinz von Foerster (1911–) due to his insights into the epistemological implications of the unspecified coding of external stimuli in the brain. The world as human beings know it, by means of their sense organs, is the product of internal mental activity. In this respect modern versions of constructivism draw on the concept of autopoiesis as it was introduced by the theoretical biologist Humberto Maturana (1928–) into epistemological discourse. According to the principle of autopoiesis every cognitive system operates on the basis of operative closure, that is to say, without direct input from its environment. Any stimulus from the environment can only stimulate the system to recursively produce its own elements and react to its own inner states. Hence any kind of knowledge or insight is an internal construction. However, this neither leads to relativism nor to the denial of an external reality. Constructivism should not be conflated with strong forms of idealism or antirealism. Yet any correspondence or mirror-theory of knowledge and truth is rejected because nothing corresponds to the internal categories, structures, and elements. Instead, categories of "compatibility," "fitting," or "viability" are of ultimate importance for constructivism since the external reality discriminates among the human constructions in favor of acceptable and fitting knowledge, assumptions, and cognitive skills. In addition, the self-referential and recursive operations inside the cognitive system produce stable states that tend to be taken as "givens" and can furthermore be socially stabilized in a broader culture.

In Niklas Luhmann's (1927–1998) operative constructivism, any production of explicit knowledge is "second-order-observation" since it is not data but other observations that are observed. This second order observation can see the distinction between the analyzed observation and its contingent and constructed character, yet without simultaneously being able to see the contingency of its own observation. What is observed are contingent constructions, but the "own" observation is—due to the blind spot within every observation—assumed to be "realistic." In modern society, where every social subsystem observes "the world" in its own way, this hybrid combination of constructivism and realism leads to a polycontextual ontology.

Due to the strong and widely held realistic assumptions within science and theology, constructivism so far has not attracted very much attention in the dialogue between religion and science. Constructivism does however argue for a nonfoundationalist view of knowledge that opens up new avenues for this dialogue. Moreover, based on the idea of autopoiesis in cognitive systems and its pragmatic orientation, constructivism vividly rejects any notion of reductionism between various cognitive approaches that seek to cope with "reality." Instead it emphasizes the limitedness and fragmentary nature of all human knowing. In addition, constructivism highlights the intimate bond between knowledge and ethics. Unexplored is the contribution of more socially oriented forms of constructivism in answering the question of the way in which, for example, the Christian faith exercises a subtle yet crucial influence on the nonreligious constructions of the wider culture. However, in order to fully embrace constructivism as religious epistemology, theology would have to accept the objectionable claim of God being a human construction for coping with life. And yet constructivism reflects at least one aspect of a central religious insight: Religious knowledge cannot secure its own stability, adequacy, and truth unless God makes Godself present in human understanding and knowing—a process often called revelation.

See also AUTOPOIESIS; CONTEXTUALISM; DUALISM; FUNCTIONALISM; NONFOUNDATIONALISM; PRAGMATISM

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GÜNTER THOMAS

CONTEXTUALISM

Contextualism comes in stronger and weaker versions. What these versions all have in common is the idea that the context, the situation, or the particularities are taken to be of outmost importance. Contextualism is a reaction against the strong emphasis on universality and common human reason characteristic of the Enlightenment tradition and modernity. The catchwords are "*Whose* truth, rationality, science, religion, ethics, or gender?" For instance, there are titles of book that read *Whose Justice? Which Rationality*? (by Alasdair MacIntyre) and *Whose Science? Whose Knowledge?* (by Sandra Harding). The idea is that it makes a crucial difference for the issues discussed whether one succeeds or fails to take the "whose" aspect or the contextual aspect into account.

Exactly what it is that could or should be contextualized in this way (whether it is, for example, theology, rationality, justice, or gender) varies from contextualist to contextualist. What also differs is the degree or depth of this contextualization. For instance, is the argument that one cannot determine what it is rational to believe without specifying who the agent is, including his or her particular historical and social context? Or is it that the standards of rationality (and not merely the particular application of them) or even truth is context-determined? If the latter, but not the former, is it the case then that rationality or truth would vary from one context (that is, culture, religion, gender, etc.) to another?

In the science-religion dialogue there are those who maintain that one cannot sensibly talk about science and religion in some abstract, universal, ahistorical, or gender-unrelated way. Instead one must be specific about, for instance, which religion (or what religious tradition within that religion), which science (or part of science), which historical period, which cultural setting, and the like, one is dealing with. For instance, John Brooke and Geoffrey Cantor argue that neither religion nor science is reducible to some timeless essence, but must be understood in their historical particularities. Science and religion are inextricable from the times in which they arise. But there are also those who make different and perhaps more radical contextual claims. D. Z. Phillips, Peter Winch, and others who have followed the Austrian-born philosopher Ludwig Wittgenstein (1889–1951) maintain that there are no practice-transcending standards of rationality, that is, science and religion do not have any standard of rationality or criteria of intelligibility in common. Therefore, it makes no sense to compare or relate them. Science and religion are two autonomous practices with totally different languages, functions, and standards of rationality.

Contextualism in many of its forms is a healthy reaction against the tendency in Western tradition to talk about, for example, "man," "human nature," "science," "religion," "reason," and "rationality" as if these are universal categories unsullied by the particularities of history, culture, traditions, gender, and the like. It is an open question, however, whether the strong emphasis of many contextualists on the local, the contextual, or the particular is just as questionable—if it is in fact to go from one ditch of the road to the other.

See also CONSTRUCTIVISM; NONFOUNDATIONALISM; PRAGMATISM

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MIKAEL STENMARK

CONTINGENCY

A proposition is *necessary* when there is no possible case in which it is false ("a vixen is a female fox"). A proposition is *contingent* when it is true in some cases and false in others ("it is raining now"). By extension, a state of affairs is contingent if it could have been other than it is. A state of affairs is necessary if there is no possible alternative to it. Most philosophers think that all physical states are contingent. Some physicists argue that the universe has to exist, whereas some theologians argue that God has to exist, but creates a contingent universe.

See also CHANCE

KEITH WARD

CONVERGENCE

When an octopus and a human being gaze at one another through the aquarium glass, they both do so through a camera-like eye. A human is a vertebrate and the occupant of the tank is a cephalopod mollusc. Their common ancestor lived more than one-half billion years ago, and since it did not have a camera-like eye the fact that humans can exchange gazes with octopuses can only mean that such an eye evolved independently. This is a classic example of convergent evolution—i.e., the emergence of a similar biological feature, not by descent from a common ancestor but from organisms that are effectively unrelated. Yet biologists also know that this eye-type has evolved independently at least four other times. For eyes to work the lens must be transparent. This property is conferred by employing particular proteins called *crystallins.* Their small molecular size enables a close packing in the watery medium of the lens, thus providing the necessary transparency. Yet the origins of human (and mammalian) and cephalopod crystallins are different. So here is an example of biochemical convergence. In both cases the crystallin is recruited from a protein originally involved with stress control; in mammals it came from a small heat-shock protein, but in cephalopods it derives from a detoxification protein. Both octopus and human end up seeing in much the same way, even though their respective ancestors could not.

Problems with the theory of convergent evolution

In the literature, such examples of convergence often provoke exclamations of "remarkable," "astonishing," and even "uncanny." It is almost as if there was a latent fear of the teleological principle being smuggled back into evolutionary biology. But are the eyes of humans and octopuses really convergent? After all, both employ the protein rhodopsin, which allows a chemical process whereby light is converted into an electrical signal that humans understand as vision. But this does not undermine the principle of convergence; it merely demonstrates that pre-existing structures will be recruited when necessary in a way analogous to the lens crystallins.

There is, however, a more serious obstacle in accepting convergence. This is in the form of the developmental gene known as *Paired-Box* (or *Pax*) *6*. This gene now has an almost iconic status: *Pax-6* "makes" eyes in most, and perhaps all, groups of animals. Does this not undermine the principle of convergence? Hardly. In the developing embryo, the activity of *Pax-6* is much more widespread. Originally it probably evolved in connection with the emerging needs for sensory systems in general: not only vision but also olfaction. *Pax-6* is necessary but not sufficient; it is little more than a genetic switch. In human and octopus, it will ensure camera-eyes, but in flies and lobsters it "makes" compound eyes.

As already noted, camera-like eyes have evolved separately at least six times, while compound eyes—most familiar in insects—have evolved independently at least three times. These examples, involving vision, are surely more significant than the other familiar instances of convergence, such as the streamlining of aquatic vertebrates or warm-bloodedness in birds and mammals. This is because such sensory assimilation implies nervous activity and a brain, with the further link to cognition and sentience.

There are also striking instances of convergence in both hearing and olfaction. Even when a nose stops being used for olfaction, as in the star-nosed mole, its tactile sense is actually strongly convergent on the neurology of vision. Even senses that are decidedly alien to humans, such as echolocation (in bats and dolphins) and the generation of electric fields in fish, show splendid examples of convergence.

Scientific and theological implications

Few textbooks on evolutionary biology neglect to mention convergence, but curiously its wider implications are seldom addressed. These concern (1) its ubiquity, which implies (2) the reality of natural selection and thereby adaptation, and (3) the inevitability of evolutionary trends. Moreover, if the natural world is seen as part of God's great order, then convergence may also have theological implications. In brief, how different can this world—or any world—really be? Put another way, if intelligent life exists elsewhere in the universe, will it be humanoid or, in Robert Bieri's phrase, the equivalent of a thinking pancake?

Convergence is, therefore, central to understanding organic evolution. First, it confirms its reality. The eyes of octopus and human are similar, but they are not identical. The structure of the lens and the position of the retina, for example, are different. Convergence does not guarantee the identical, only the emergence of particular biological properties. Second, the ubiquity of convergence implies the prevalence of selective pressure: how else could biological systems come so closely to resemble each other? So too with adaptation; it is a biological reality and not some incidental by-product of effectively random processes. Third, the reality of convergence has the implicit assumption that starting points will be disparate, but there will be defined and repeatable evolutionary trajectories in evolution. Trends are real, and if the end-point is not perfect, is it emphatically better than what came before.

Yet all this is strongly at odds with a widespread perception that contingent happenstance is the determining reality in evolution. Thus, to paraphrase American paleontologist Stephen Jay Gould's metaphor of the tape of life, if the history of the world were to be re-run, the end result would utterly different. Historians might meditate on the untimely demise of Hitler or the death at an advanced age of Alexander the Great, but the consensus amongst biologists is that even a nudge in one direction half a billion years ago would preclude entirely the emergence of humans. As individuals this must be true, given that all humans were conceived by their parents against the odds. Yet biologically this view is deeply credulous. It is no accident that those who suppose the emergence of humans to be the product of individual and contingent history, also believe that humans are not only free (as indeed they are) but may mold their morality to a scheme of their choosing.

The realities of biological evolution and the inevitability of convergence suggest, however, a new view of life. Creation presupposes a history and an end-point, but this does not constrain choice and acceptance (or the opposite). The universe is so arranged that sooner or later, somewhere or other, certain properties, biological and ultimately spiritual, will emerge. The quip by British geneticist and physiologist J.B.S. Haldane remarking upon the creator's inordinate fondness for beetles is thereby turned on its head. Creation is indeed rich, but the modalities of convergence suggest that ultimately it is otiose to speak of accidents. Seeded in the act of creation was the inevitability of sentience endowed with free will.

See also ADAPTATION; CHANCE; DESIGN; EVOLUTION; EVOLUTION, BIOLOGICAL; SELECTION, LEVELS OF

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SIMON CONWAY MORRIS

COPENHAGEN INTERPRETATION

The Copenhagen Interpretation, developed primarily by Danish physicist Niels Bohr (1885–1962) and other researchers in Copenhagen in the first third of the twentieth century, is the standard interpretation of quantum mechanics. It ascribes physical reality only to observed reality. Quantum mechanics can predict only the probability that measurements will have particular outcomes. No observation has ever been found to conflict with the experimental predictions of this theory. However, there is much debate about the correctness of this interpretation of the measurement process, and there are several rival interpretations of quantum mechanics, notably the Many Worlds Interpretation proposed in 1957 by physicists Hugh Everett and John Wheeler. A major problem of the Copenhagen Interpretation is the lack of a precise definition of what constitutes a "measurement" or an "observation." It is also problematic if a theory of quantum cosmology is to be developed because the Copenhagen Interpretation requires an "observer" for the universe.

See also EPR PARADOX; MANY-WORLDS HYPOTHESIS; PARADOX; PHYSICS, QUANTUM; SELF-REFERENCE

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JOHN D. BARROW

COSMOLOGICAL ARGUMENT

Cosmological arguments aim to establish the causal or explanatory dependence of the world on a wholly independent being, usually identified with God. These arguments typically proceed from the claim that familiar things are dependent in various ways upon other things—that is, for their origin, movement, and continued existence. The crux of traditional cosmological arguments is the contention that not every being can be dependent in the relevant way; that is, any chain of dependence must ultimately be grounded in a being that admits of no such dependence.

History of cosmological argument

The history of cosmological arguments goes back at least to Aristotle, though his understanding of the Prime Mover bears little resemblance to theism. After Aristotle, the history divides naturally into two categories: (1) In the Middle Ages, philosophers in all three major theistic traditions defended cosmological arguments. Prominent among them were Ibn Sina (Avicenna), St. Thomas Aquinas, and Moses Maimonides, all thinkers within the Aristotelian metaphysical framework; and (2) By the early modern period, the principles of Aristotelian metaphysics that had supported cosmological arguments were no longer in vogue. But it proved natural to formulate a cosmological argument in fresh terms, as Samuel Clarke did in 1705. Clarke insisted that whatever comes to be is dependent on other things to provide an account or reason for its existence, and he argued that an account is incomplete if it is not ultimately grounded in some independent thing. Clarke's contemporary, Gottfried Leibniz, also defended a cosmological argument, while both David Hume and Immanuel Kant provided famous criticisms. Variations on deductive cosmological arguments (like that of Clarke) are the most important in the literature, and are still discussed today.

Deductive cosmological argument

It is incontrovertible that some things and events are explanatorily dependent on other things in the way described above. But a central question in debates over cosmological arguments of the deductive sort concerns the possibility of an infinite series of things or events, each providing an adequate explanation for the existence (or motion) of the next. Setting Aristotelian principles aside, there is no obvious way to rule out such a series based on contemporary physical theory or metaphysical accounts of causation. But many cosmological arguments reject the possibility of such a series on the grounds that an explanation is incomplete if that which explains (the *explanans*) requires explanation itself. This implies that a complete explanation for any thing or event must ultimately be grounded in something that has no explanatory dependence. Finally, it is often claimed that only a necessary being (a being that could not have failed to exist) requires no explanation for its existence. And God is considered the most natural example of a necessary being with causal powers.

Two responses to this argument are common. First, the critic can reject the notion of complete explanation just sketched. Since every individual thing in an infinite series of dependent beings is explained by the thing immediately prior to it, the existence of that individual remains intelligible despite the lack of an independent being in the series. Second, the critic can claim that the infinite series itself provides a complete explanation for the existence of whatever follows it. But the series itself is not dependent on anything else for an explanation.

In order to rule out both of these responses, some theists have propounded a very strong principle: not just the familiar facts of experience, but *every contingent state of affairs* must have an explanation outside of itself (the Principle of Sufficient Reason). If this principle were true, not only would every individual in an infinite series of causes require explanation, but the existence of the series itself would require explanation. (A contingent state of affairs is one that might not have been the case.) However, the principle seems overly strong and quite difficult to motivate. In fact, even a theist has good grounds for rejecting it. After all, traditional theism maintains that God created freely and could have chosen otherwise; so God's deciding to create the world is a contingent occurrence. And since it is contingent, it cannot be completely explained (i.e. deduced) from any necessary truths about God. In response, the theist could weaken the original principle somewhat, allowing that only free acts of persons are suitable contingent grounds for explanation. But if exceptions to the rule are allowed, why not allow the unexplained existence of an infinite series, or of a first contingent physical event like the Big Bang?

It is important to clarify that even a successful deductive cosmological argument would not establish the truth of theism. First, such an argument would not entail the conclusion that there is a *single* independent and necessary being, since there could be a number of them. Second, even if there were only one such being, a cosmological argument would provide no guarantee that the being is personal, all-powerful, or good. (Perhaps it is an impersonal force or a great demon.) But these limitations do not mean that cosmological arguments are useless for justifying theism. For a great many competing theories would be ruled out by a successful deductive cosmological argument.

Evidential cosmological argument

An importantly different kind of argument is presented by Richard Swinburne's *The Existence of God* (1979). Swinburne rejects cosmological arguments aiming at deductive proof. Rather than insisting that some principle of reason rules out the possibility that the physical universe could simply exist unexplained, he compares the creation hypothesis with its rivals by using criteria such as simplicity and explanatory power. In this respect, the existence of God is treated as an explanatory postulate akin to the existence of electrons. Swinburne builds a cumulative case based on several types of facts that he believes are best explained by theism. Among these facts is the mere existence of a complex and contingent physical universe. Nevertheless, because there is no established standard for comparing the merits of ultimate explanations, the evidential cosmological argument is widely considered inconclusive at best. Swinburne's conclusions receive a sophisticated critique in J. L. Mackie's *The Miracle of Theism* (1982).

See also ARISTOTLE; AVICENNA; CAUSATION; COSMOLOGY; MAIMONIDES; ONTOLOGICAL ARGUMENT; TELEOLOGICAL ARGUMENT; THEISM; THOMAS AQUINAS

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COSMOLOGY

Many, perhaps all, early cosmologies or descriptions of the structure of the world were anthropocentric (focused on the role and fate of human beings) and they envisioned a universe subject to whims of gods. As such, cosmology and religion were closely intertwined.

From the ancient Greeks through the Middle Ages, over some two millennia, the geocentric cosmology or worldview of Aristotle (384–322 B.C.E.) dominated much of the Western intellectual world. Circular and unalterable heavens rotated around the Earth, which was motionless in the center of the one and only world. Created during roughly the same period and in the same regions of the world, Aristotelian philosophy and Biblical accounts of cosmology and cosmogony are, not surprisingly, congruent in some respects. Aristotle's teleological explanations assumed that the world was fulfilling a purpose formed by a superhuman mind; Christian philosophy also is inherently meaningful and purposive.

During the Middle Ages, Aristotelian cosmology was subordinated to religious concerns. In the sixteenth century Nicolaus Copernicus (1473–1543) displaced the Earth, though not the solar system, from the center of the universe, and increasingly from the center of God's attention as well. In the seventeenth century Galileo Galilei (1564–1642) destroyed Aristotelian cosmology. The subsequent mechanical cosmology of Isaac Newton (1642–1727), though initially requiring God's intervention to keep the planets circling the sun, eventually replaced God completely with the universal law of gravity.

Early in the twentieth century, the American astronomer Harlow Shapley (1885–1972) showed that the solar system is not at the center of our galaxy, but off to the side, and that our galaxy is many times larger than previously contemplated. A few years later, Edwin Hubble (1889–1953) showed that our galaxy is but one of many island universes, and that the acentric universe is expanding. Each new cosmological discovery displaced humankind farther from the center of the universe and seemed to render humans less significant in an increasingly immense universe.

A contemporary resurgence of dialogue between scientific cosmology and religious thought late in the twentieth century involved yet another version of the traditional design argument for God. The Anthropic Principle noted that values of the fundamental constants of nature (the speed of light, Planck's constant, etc.) and the fundamental physical laws are "fine-tuned" to precisely what is needed for the evolution of life. As with earlier cosmologically based arguments for the existence of God, the Anthropic Principle has proven highly vulnerable to theory-change in science. The inflationary Big Bang cosmological model now explains much fine-tuning without recourse to God.

The history of the relationship between cosmology and religion, particularly in Western thought, has been enlivened by changes in cosmological understanding and beliefs. As the Earth has been increasingly displaced from the center of the universe and observed phenomena have been increasingly brought under the rule of natural physical laws, humankind's relationship with and understanding of God has required revisions.

See also ANTHROPIC PRINCIPLE; BIBLICAL COSMOLOGY; BIG BANG THEORY; BIG CRUNCH THEORY; FEMINIST COSMOLOGY; GALILEO GALILEI; GEOCENTRISM

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COSMOLOGY, PHYSICAL ASPECTS

The scientific understanding of the origin, nature, and possible future of the universe dramatically changed during the twentieth century. This burst of scientific discovery triggered a complex series of responses among religious thinkers, particularly after about 1960, which marks the beginning of the contemporary resurgence of dialogue between science and religion. The recent interaction between scientific cosmology and religious thought is one of the richest and most instructive examples of contemporary science-religion dialogue.

Theologians have related physical cosmology most often to the doctrine of creation. In its Christian form, creation theology typically includes two components: *creatio ex nihilo* (creation out of nothing) and *creatio continua* (continuous creation). Judaism and Islam explicate similar ideas, but the formal distinction is an invention of Christian theology to express different features of the God-world relation. *Creatio ex nihilo* stresses the dependence or contingency of all that exists on God as its transcendent source while *creatio continua* stresses God's continuing and immanent action in the universe. Together, these ideas portray God both as the ultimate source of nature's causal efficacy, faithfully maintaining its regularities, which we describe in terms of the laws of nature, and as creating in time by acting in, with, under, and through the laws of nature, bringing forth the order, beauty, and complexity of the physical world and the rich diversity found in the biological evolution of life.

Creation *ex nihilo* has been explored extensively in relation to two particular features of Big Bang cosmology: $t = 0$, which represents the beginning of time and thus the age of the universe, and the Anthropic Principle, which points to the remarkable conditions that the fundamental constants and the laws of nature must meet if the evolution of life in the universe is to be possible. These will be discussed in turn, each followed by theological discussions of its significance for *creatio ex nihilo*. The *creatio continua* form has been discussed in terms of the temporal, developmental, and historical character of the universe; it will not be treated here. Finally, inflationary and quantum cosmologies will be discussed in advance of a survey of theological responses.

Big Bang cosmology

During the decade following the 1905 publication of his Special Theory of Relativity, Albert Einstein worked on a relativistic theory of gravity. His basic insight was to reconceptualize gravity as the curvature of space-time instead of as a (Newtonian) force in Euclidean space. According to Einstein, masses move along geodesics, curves describing the shortest possible path in space-time. Their motion, in turn, alters the curvature of space-time, thus giving the field equations of the General Theory of Relativity their complicated nonlinear form.

Shortly after the discovery of the General Theory of Relativity, solutions to Einstein's equations were developed for two distinct classes of problems: (1) point masses, which when applied to the solar system led to several key tests of the theory and their eventual confirmation (including the deflection of starlight by the sun and the precession in the perihelion of the orbit of Mercury); and (2) dust, which when eventually applied to the distribution of galaxies and galactic clusters described the universe as expanding in time. Beginning in the 1920s, telescopic observations by Edwin Hubble showed that galaxies were indeed receding from us and at a velocity proportional to their distance. In essence, the expansion of the universe had been discovered.

There are in fact three standard types of expansion possible. In the so-called closed model, the universe has the shape of a three-dimensional sphere of finite size. It expands up to a maximum size, approximately one hundred to five hundred billion years from now, then contracts, eventually collapsing to vanishing size with infinite temperatures and densities. The so-called open model has two variations, one in which the universe is flat, and one in which it is saddle-shaped. In both versions of the open model, the universe is infinite in size. In both cases the universe will expand forever and cool towards absolute zero. The future of these three models is often used to characterize them as "freeze" (open) or "fry" (closed).

All three models came to be called Big Bang models because they describe the universe as having a finite past life of twelve to fifteen billion years and as beginning in a singularity, an event of infinite temperature, infinite density, and zero volume in which the laws of physics as we know them break down. Since the age of the universe t is calculated as starting here, it is convenient to label the singularity "$t = 0$"; technically this event is referred to as an *essential singularity.* In the 1960s, Stephen Hawking, Roger Penrose, and Robert Geroch proved key theorems demonstrating that the existence of an essential singularity such as $t = 0$, given Einstein's General Theory of Relativity, was unavoidable.

The relevance of $t = 0$ to creation *ex nihilo*

To what extent is $t = 0$ relevant to the doctrine of creation *ex nihilo*? Responses have ranged widely from direct relevance to complete irrelevance.

Direct relevance. For some scholars, the scientific discovery of an absolute beginning of all things (including time) provides empirical confirmation, perhaps even proof, of divine creation. This was the position taken by Pope Pius XII in 1951 in an address to the Pontifical Academy of Sciences. In 1978 Robert Jastrow, then head of NASA's Goddard Institute for Space Studies, spoke metaphorically about scientists who, after climbing the arduous mountain of cosmology, came to the summit only to find theologians there already. The idea that $t = 0$ provides strong, even convincing, support for belief in God is frequently advanced by conservative and evangelical Christians such as Hugh Ross. Early in the debate, Lutheran theologian Ted Peters advanced a more nuanced argument elucidating the theological importance of a beginning to the universe in terms of "consonance" between theology and Big Bang cosmology. A sophisticated argument for the temporal finitude of the universe based on $t = 0$, as well as on an argument that rejects the possibility that the universe is also actually infinite in size, has been developed by philosopher William Craig, partially through an explicit debate with atheist Quentin Smith. More recently, philosopher Phil Clayton has suggested that contemporary cosmology affords a clear case of divine activity.

$t = 0$ also has served indirectly to inspire the construction of an alternative, and quite successful, cosmology. In the 1940s, Fred Hoyle, an outspoken atheist, together with colleagues Hermann Bondi and Thomas Gold, constructed a cosmology that would have no temporal beginning or end. Their "steady state cosmology" depicted the universe as eternally old and expanding exponentially forever. For two decades, the Big Bang and the steady state models seemed equally viable given the empirical evidence then available. By the mid-1960s, however, the Big Bang model was vindicated, at least in most scientists' minds, by the discovery of the microwave background radiation, the successful prediction of the cosmological abundances of hydrogen and helium, and other effects. What is important here, however, is Hoyle's motivation in developing the steady state cosmology. One reason, although probably only secondary, was his concern that Big Bang cosmology seemed, at least in the public mind, to support Christianity. Of course, the scientific community must test strictly any cosmological proposal—steady state or Big Bang—regardless of its possible ideological origins. As philosophers put it, the "context of discovery" should not influence the "context of justification." Nevertheless, the story of Hoyle demonstrates that very fruitful ideas can come from "extra scientific" disciplines, such as philosophy and theology, and lead even if indirectly to scientific theories with testable consequences.

Complete irrelevance. Several of the most important scholars in the theology and science interaction see *creatio ex nihilo* as an entirely philosophical argument regarding contingency for which specific empirical evidence is irrelevant. This includes scientists such as Arthur Peacocke, John Polkinghorne, Bill Stoeger, and Ian Barbour (in his early writings) as well as Thomistic scholars such as Steven Baldner and William Carroll.

Indirect relevance. There are a variety of positions that one can take between the two extremes of direct relevancy and complete irrelevancy. Those who find various forms of indirect relevance include scientists such as Ian Barbour (in later work), George Ellis, Walter Hearne, and Howard Van Till; and philosophers and religious scholars such as Ernan McMullin, Nancey Murphy, Ted Peters (in later work), Mark Worthing, and Robert John Russell. Russell's way of articulating indirect relevance is to point out that $t = 0$ is relevant to the aspect of contingency within the idea of creation to various degrees depending on the sort of contingency considered. For example, three basic types of contingency can be distinguished: global contingency, local contingency, and nomological contingency. The first of these, global contingency, includes both the existence of the universe as such (global ontological contingency) and contingent theoretical or empirical aspects of the universe as a whole (global existential contingency). The particular sort of contingency associated with $t = 0$ would come under the latter—it is a form of past temporal finitude, which is a form of finitude and thus a species of global existential contingency—but not the former. Thus, the universe's existence and its beginning relate to different strands of global contingency. It is important to note, however, that the infinite size and infinite future of the two open models of the universe argue against contingency in the very same respect. In other words, if $t = 0$ is "consonant" with creation theology in respect of "global existential contingency" then these infinities are "dissonant" with creation and other theological doctrines, such as the eschatological views of Western religions, in exactly the same respect.

The Anthropic Principle

The term Anthropic Principle was coined by physicist Brandon Carter in 1974 to bring together various apparent coincidences about the universe that had received scattered attention throughout the twentieth century. Although formulated in a variety of ways, in its strongest form the Anthropic Principle poses the following question: How are we to explain the fact that the values of the fundamental constants of nature (e.g., the speed of light, Planck's constant, etc.) and the form of the fundamental physical laws are "fine-tuned" to precisely what is needed if the evolution of life is to be possible? Estimates have been made suggesting that if the values of the natural constants differed from their actual values by one part in a million, it would have been impossible for life to have evolved in the universe.

To some, then, the universe seems "fine-tuned" for life, suggesting a cosmological version of the traditional design argument for God. Opponents have deployed a variety of "many-worlds" arguments to suggest that there are many universes besides our own, each with different values of the natural constants, perhaps even different physical laws. In that scenario, by definition, life would evolve in the particular universe that satisfies the conditions for life but not in others, which explains cosmic fine-tuning without having to invoke a designer to explain the anthropic coincidences. What are the relative scientific, philosophical, and theological merits of these opposing positions?

As early as 1979, Peacocke gave the Anthropic Principle an indirect but important role within his discussion of the doctrine of creation, using metaphors of God as elaborating a fugue and as a bell-ringer sounding the changes. George Ellis has explored what he calls the "Christian Anthropic Principle," combining design perspectives with a theology of divine omnipotence and transcendence, drawing from William Temple. Nancey Murphy, however, treats Ellis's thesis as an argument for God. She reconstructs Ellis's paper to show that theology can be seen as a science and that cosmological fine-tuning can serve as an "auxiliary hypothesis" in such a theological program. Richard Swinburne and John Polkinghorne have also drawn on the Anthropic Principle in constructive ways.

The endorsements are not universal, however. Theologian Mark Worthing cautions that the "designer" of the universe need not be the creator God of theism: both a divine demiurge, including the universe itself, as Richard Dawkins suggests, or an emerging divinity, as John Barrow and Frank Tipler propose, take into account the empirical evidence of fine-tuning. According to Barbour, the theological virtues of construing the Anthropic Principle as a modern design argument are minimal.

Philosopher John Leslie's overall evaluation is that the two opposed sides are equally strong as arguments but also equally incorrect because a fully adequate conception of God is neutral to cosmological details—Leslie articulates God in terms of a neo-Platonic aesthetic/ethical principle. Most variations on the Platonic idea of God as the form of the Good and the neo-Platonic idea of God as Ground of Being are neutral to cosmological details, and their defenders are inclined to regard design arguments based on the Anthropic Principle and the many-worlds opponents as premature. Historian of science Ernan McMullin points out that the Anthropic Principle is highly vulnerable to theory-change in science. A quantum cosmology needs to gain widespread acceptance before the force of the Anthropic Principle can be assessed properly.

The Anthropic Principle can, however, play a fruitful role if incorporated within ongoing constructive theology, illuminating its inner meaning and suggesting connections between theological topics we might not otherwise have recognized. For example, the Anthropic Principle underscores the key role that Planck's constant plays in the particular overall structure of the universe, a role that a theology of creation *ex nihilo* would need to take seriously. The same constant may be a critical factor in compatibilist discussions of free will and thus for theological anthropology: For us to act freely, nature at the physical level must, arguably, be indeterministic. It also functions pivotally in some approaches to noninterventionist divine action, particularly in the context of theistic evolution.

Inflationary and quantum cosmologies

Since the 1970s, scientists have pursued "inflationary Big Bang" and beyond that "quantum cosmologies." The motivation for this has been both to solve a variety of technical problems in the standard Big Bang model and to blend cosmology with quantum physics, which studies atomic and subatomic physical systems. The term *quantum cosmology* sounds oxymoronic, but the Big Bang entails that the very early universe was extremely small and thus subject as a whole to quantum physics. Physicists were also seeking to produce a theoretical unification of gravity and the other physical forces (the electroweak and strong nuclear forces), a unity that is thought to be physically evident only at extraordinarily high energies such as those present in the early stages of the Big Bang.

With the introduction of the "inflationary Big Bang" scenario by Alan Guth and colleagues in the 1970s and further developments in this direction in the 1980s, the technical problems were basically solved. According to inflation, the extremely early universe (roughly from $t = 0$ until the Planck time, which is 10^{-43} seconds) expands extremely rapidly, then quickly settles down to the expansion rates of the standard Big Bang model. During inflation, countless cosmic domains may arise, separating the overall universe into huge portions of space-time in which the natural constants and even the specific laws of physics might vary. The effect of inflation on the problem of $t = 0$ is fascinating, however, because the Hawking-Penrose theorems mentioned above do not apply during the inflationary epoch. In these cosmologies we may never know whether or not an essential singularity was part of the universe's history.

Many physicists have proposed methods to unify quantum physics and gravity, subsequently applying the results to create quantum cosmologies: Hawking and Jim Hartle, Andrei Linde, Chris Isham, Guth, Hawking and Alan Turek, and others. All of these proposals are still highly speculative, but there are some indications of what different quantum cosmologies might look like, including models with or without an initial singularity (eternal inflation), with open or closed domains embedded in an open or a closed megauniverse, and so on. In most quantum cosmologies, our universe is just one part of an eternally expanding, infinitely complex megauniverse. Quantum cosmology is a highly speculative field chiefly because the underlying theories of quantum gravity are notoriously hard to test empirically, and they lift the philosophical issues already associated with quantum mechanics to a much more complex level since the domain of application is now the entire universe.

***t* = 0 revisited in inflationary and quantum cosmologies.** Given the speculative status of quantum cosmology, some scholars have kept the theological conversation focused on the standard Big Bang model. Others, though, have asked what effects quantum cosmology might have on their theology of creation.

One argument is to invoke, once again, the argument for God from the sheer existence of the universe. Thus, even without an initial singularity, even the endless number of universes suggested by inflation and most quantum cosmologies is contingent in some sense and so invites a creator God as their necessary complement and creative source. A related point is that the prior universe or ensemble of universes out of which our universe arose includes quantum fields governed by the laws of physics (both of which are needed to give what passes in quantum cosmologies for a scientific account of the quantum creation of the universe). But the Christian view of *creatio ex nihilo* relies on the meaning of "nothingness" out of which God created all that is as the absolute lack of anything. Hawking, for example, seems to argue in part in this way in *A Brief History of Time* (1988). At times in the book Hawking seems to agree that without a *t* = 0 there is nothing left for God to do, but not at the end, for he also writes: "even if there is only one possible unified theory, it is just a set of rules and equations. What is it that breathes fire into the equations and makes a universe for them to describe? The usual approach of science … cannot answer the question of why there should be a universe for the model to describe" (p. 190).

It is also possible to see, in the debates over approaches to quantum cosmology, the striking presence of extrascientific factors. A fascinating example occurs in comparing proposals by Penrose and Hawking and Hartle. In Penrose's view, our universe arises as an arbitrary quantum fluctuation in a homogeneous background superspace filled with quantum fields. But why should any point in superspace be singled out as creating a universe like ours? As Isham puts it, the problem was preempted by the response of Augustine of Hippo (354–430) to the question of what God was doing before God made the universe. Augustine's answer was that God did not create the universe in time, since the decision as to which point in time to create it would be arbitrary and would imply that God's will is mutable. Instead Augustine claimed that God created time along with the creation of the universe. But as Isham points out, the same reasoning leads us to reject Penrose's approach: It is thoroughly arbitrary to pick a creation point in superspace. The Hawking-Hartle model, on the other hand, circumvents the need for such a point, making it more attractive to many scientists. This is a striking example of the potentially positive role philosophy and theology can play in stimulating new insights and directions of inquiry within the natural sciences.

In short, then, inflation and quantum cosmologies can point to the grandeur and mystery of God's creativity and undercut our anthropocentrism by stressing a creation far beyond anything we could ever observe, one in which God relishes and delights in its sheer diversity. Moreover, none of the scientific cosmologies explains why the "universe" exists as such, leading us once again to the possibility of recognizing God as the creative ground of being.

Anthropic principle revisited in inflationary and quantum cosmologies. In the inflationary Big Bang scenario, the "universe" (or megauniverse) includes an infinity of domains, each a "universe" unto itself, with its own values of the fundamental constants, perhaps even differing laws of nature. In Linde's quantum cosmology, the universe eternally inflates into an infinity of bubble universes, themselves inflating into others endlessly. These scenarios suggest a far more ontologically stark "many-worlds" character than those of standard Big Bang cosmology, though they are far less defensible empirically. At least in theory they seem to explain fine-tuning by means of a kind of "cosmic Darwinism," rendering the design argument irrelevant.

Those defending an application of the Anthropic Principle to a design argument tend to stress the technical and philosophical problems with inflation and quantum cosmologies. They also tend to appeal to Ockham's Razor against many-worlds or multiverse theories and in support of the Big Bang, and they invoke God as the simplest explanation of fine-tuning. Critics of an application of the Anthropic Principle to a design argument tend to view standard Big Bang cosmology as outdated while appealing to philosophical criticisms to the effect that judgments of design are unreliable because they are necessarily limited by human imaginations.

Conclusion

Perhaps the most important result to emerge from the shifts in cosmology over the late twentieth century is the emergence of the hot Big Bang as a "permanent" description of *our* universe from the Planck time some twelve to fifteen billion years ago until the present. Gone is the time when the Big Bang theory enjoyed a serious challenger in the form of Hoyle's steady state model, with its picture of a single, ever-expanding universe whose fundamental features were time-independent. Instead the domain of debate has shifted to the pre-Planck era and what might lie endlessly "before" the Big Bang in quantum superspace. We have witnessed what Joel Primack and Nancy Abrams call an "encompassing" revolution as distinguished from the kind of Kuhnian "replacing revolution" one usually thinks of when scientific paradigms change. In such an encompassing revolution, the new paradigm contains the old one as a limit case; that is, quantum cosmology encompasses Big Bang cosmology as a special case when quantum effects can be ignored. To paraphrase a point made by Charles Misner, we can have confidence in relying on the Big Bang scenario because we know just where it fails: prior to the Planck time. In this sense the Big Bang is here to stay.

See also ANTHROPIC PRINCIPLE; BIG BANG THEORY; COSMOLOGY; COSMOLOGY, RELIGIOUS AND PHILOSOPHICAL ASPECTS; CREATIO CONTINUA; CREATIO EX NIHILO; INFLATIONARY UNIVERSE THEORY; MANY-WORLDS HYPOTHESIS; QUANTUM COSMOLOGIES; STEADY STATE THEORY; T = 0

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ROBERT JOHN RUSSELL

Cosmology, Religious and Philosophical Aspects

Presumption of inevitable battle often dominates discussions of interactions between cosmology and religion, and dictates the history produced. The image of war, though modified since Andrew Dickson White's 1897 *History of the Warfare of Science with Theology in Christendom,* persists.

As he watched workers chip away at the ice barrier across the River Neva binding together the piers and the old fortress of the czars, White, the American ambassador to Russia, likened the ice to outworn creeds and noxious dogmas attaching the modern world to medieval conceptions of Christianity. He hoped that both barriers might be swept away by floods, the former by water and the latter by increased knowledge and new thought. White had experienced dogmatic opposition in the course of steering through the New York state legislature the enabling legislation in 1868 for Cornell University in Ithaca, which he subsequently guided and served as its first president. Clergymen had warned against the atheism of the proposed university with its emphasis on science, but White refused to stretch or cut science to fit "revealed religion." The controversy bore in upon White a sense of antagonism, subsequently reflected in his book. "In all of modern history," White wrote, "interference with science in the supposed interest of religion … has resulted in the direst evils both to religion and to science" (p. viii).

Early interaction between cosmology and religion

The ancient Greek philosopher Anaxagoras (500–428 B.C.E.) was seemingly an early victim of the conflict between cosmology and religion. Greek cosmology moved away from astrological superstition, magical powers, and myth toward a more rational spirit and a picture of a universe with unchanging ways ascertainable by human reason but beyond the control of human action. Anaxagoras' new theory of universal order collided with popular faith—the belief that gods ruled the celestial phenomena—and he was expelled from Athens. Impiety, however, may have been an incidental charge; the indictment also included an accusation of corresponding with agents of Persia. The rise of a new scientific attitude and mode of thought may have accelerated the downfall of traditional religious and political beliefs, and helped shape their replacements.

An earlier religious belief of the Babylonians—that the movements of celestial bodies functioned as a sort of message board with which the gods foretold human affairs—had promoted observations and mathematical analysis. Many ancient religions associated planets with gods and found religious significance in configurations of celestial arrangements. Egyptian temples were aligned with specific stars and Stonehenge in southwestern England faced sunrise at summer solstice.

Religion motivated Greek as well as Babylonian cosmological studies. Plato's fourth-century B.C.E. conception of cosmic order was permeated with ethical overtones and moral significance, and during the second century C.E. Ptolemy cultivated cosmology particularly with respect to divine and heavenly things. He wrote "I know that I am mortal and the creature of a day; but when I search out the massed wheeling circles of the stars, my feet no longer touch the Earth, but, side by side with Zeus himself, I take my fill of ambrosia, the food of the gods" (p. 55).

Similarly for Christians, "The Heavens declare the glory of God" (Ps. 19:1). During the early Middle Ages, cosmology was regarded as a handmaiden, subservient to theology, pursued not for its own sake but for its usefulness in the interpretation of Holy Scripture. Both Augustine of Hippo (354–430) and Thomas Aquinas (c. 1225–1274) insisted that the truth of scripture is inviolable. Given possible alternative interpretations of scripture, however, they warned against rigid adherence to any one of them. A hasty choice could prove detrimental to faith, were science later to prove that choice untenable. Study and contemplation of the cosmos, the perfect expression of divine creativity and providence, were for some a way to know God.

Scientific knowledge was not precious enough to prevent the Roman emperor Justinian (483–565), a Christian, from closing the Academy at Athens in 529 C.E. and forbidding pagans to teach. Leading philosophers left Athens for Persia, though some returned after a few years and the Academy may have continued in some form. Further impeding cosmological inquiry was a growing inability to recruit competitively against the church as a profession for bright young minds. Cosmological study had received little patronage in ancient societies, with the exception of the Museum at Alexandria, and its precarious position was not altered significantly under early Christianity.

Greek science almost disappeared from Western Europe between 500 and 1100 C.E., before it was recovered through translations of the works of Aristotle and Plato, and in Arabic treatises and commentaries on Aristotle. Cosmological studies flourished within Muslim culture and civilization, sometimes under rulers interested in astrology. A few Islamic traditionalists criticized these practices for leading to the establishment of schools for heretics and the teaching of magic. The Istanbul observatory, built in 1577, was torn down shortly after its completion. In the wake of the famous comet of 1577 there had followed in quick order plague, defeats of Turkish armies, and deaths of several important persons. These misfortunes were attributed to the attempt, manifested in construction of the observatory, to pry into the secrets of nature.

After transmission from Islam to the West, Aristotelian cosmology fused with Christian theology into Scholasticism. In this form, Aristotle's cosmology permeated thought in Western Europe between roughly 1200 and 1500, especially in universities. The Aristotelian position that necessary cosmological principles can be known conjured the specter of truths necessary to cosmology but contradictory to dogmas of the Christian faith. For example, the Aristotelian assertion that the world had no beginning and no end, and thus was indestructible, seemingly conflicted with the possibility of a Day of Judgment. In 1270 the bishop of Paris condemned several propositions derived from the teachings of Aristotle, including the eternity of the world and the necessary control of terrestrial events by celestial bodies. In 1277 Pope John XXI directed the bishop of Paris to investigate intellectual controversies at the university. Within three weeks the bishop condemned 219 propositions. Excommunication was the penalty for holding even one of the damned errors.

Though intended to contain and control scientific inquiry, the condemnation may have helped free cosmology from Aristotelian prejudices and modes of argument. The Scientific Revolution may owe something to the condemnation of 1277, even if cosmologists waited until the seventeenth century to repudiate Aristotelian cosmology.

The condemnation of 1277 with its emphasis on God's absolute power undisputedly led to the nominalist thesis. The Aristotelian position that the necessary principles of cosmology and physics can be established was rejected. Cosmology now was understood to be a working hypothesis in agreement with observed phenomena. The truth of any particular hypothesis could not be insisted upon, because God could have made the world in a different manner but with the same observational consequences. Cosmologists might come to conclusions, but they could not insist that their conclusions limited God's power to have created the world in another way. Tentative, but not necessary, cosmological theories posed no challenge to religious authority.

While conceding the divine omnipotence of Christian doctrine and acceding to religious authority, the nominalist, instrumentalist, positivist thesis also freed science from religious authority. It was a convenient stance in a time when religious matters were taken seriously and heretical cosmological thoughts could place their adherents in serious trouble with powerful ecclesiastical authorities. In the new intellectual climate, imaginative and ingenious discussions flourished.

Hypothetical cosmologies, however, were not the stuff of revolution. It was not until the goal of "saving the appearances," as the nominalist endeavor has been called, was replaced with a quest to discover physical reality, that Aristotelian cosmology was destroyed and replaced with a new worldview. Confidence that the essential structure and operation of the cosmos is knowable seems to have been a prerequisite to the work of Nicolaus Copernicus (1473–1543), Galileo Galilei (1564–1642), Johannes Kepler (1571–1630), and Isaac Newton (1642–1727). Some of their necessary cosmological principles would conflict with dogmas of the Christian faith.

To account for the apparent daily motion of the heavens, Copernicus placed the sun in the center of the universe and the Earth in revolution around the sun and rotating on its axis. An unauthorized foreword to Copernicus's 1543 *De revolutionibus orbium caelestium* (*On the Revolutions of Heavenly Spheres*) presented the heliocentric theory as a convenient mathematical fiction. Copernicus, however, believed that he was describing the real motions of the world.

Copernicus anticipated criticism, acknowledging in the preface to *De revolutionibus* "that to ascribe movement to the Earth must indeed seem an absurd performance on my part to those who know that many centuries have consented to the establishment of the contrary judgment, namely that the Earth is placed immovably as the central point in the middle of the Universe" (p. 137). Copernicus, however, did not anticipate criticism from the Catholic Church, in whose service he had long labored as a canon and advised the papacy on calendar reform. Indeed, Copernicus dedicated his book to Pope Paul III, in hope that "my labors contribute somewhat even to the Commonwealth of the Church, of which your Holiness is now Prince. For not long since the question of correcting the ecclesiastical calendar was debated" (p. 143).

Citation of scripture against the new cosmology was not long in coming. Even before Copernicus' book was published, the reformer Martin Luther (1483–1546) warned that "this fool wishes to reverse the entire science of astronomy; but sacred Scripture tells us that Joshua commanded the Sun to stand still, and not the Earth" (Josh. 10:13). Literal adherence to the Bible was the foundation of Protestant revolt against Catholic religious hegemony. Prior to the Counter-Reformation, the Catholic Church was more liberal in its interpretation, and more accepting of Copernican cosmology. It was taught in some Catholic universities and used for the new calendar promulgated by Pope Gregory XIII in 1582.

Galileo and the Church

Revolutions in science, as in politics, often go beyond the limited changes that the people who start a revolution have in mind. In Copernican cosmology, the rotation of the Earth caused the stars' observed motion. Hence, the notion of the starry sphere that carried the stars around was obsolete, and soon human imagination distributed the stars throughout a perhaps infinite space. Also, the Earth was no longer unique; now it was merely one of several similar objects in the solar system. And humankind was but one of possibly many intelligent inhabitants of the universe. Soon questions arose: If the Earth were a celestial planet, how did it differ from the divine heavens? Had each planet been visited by an Adam and an Eve? Faith in an anthropocentric universe lay shattered, leaving humankind's relationship with God uncertain. John Donne's 1611 poem *The Anatomy of the World,* with its opening line the "new Philosophy calls all in doubt," and later "all Relation: Prince, Subject, Father Son, are things forgot," refers to Christian morality as well as the physical locations of the sun and the Earth.

That the Earth was no longer unique was most dramatically emphasized by Galileo. His telescopic observations of the moon's surface emphatically demanded the revolutionary conclusion that the moon was not a smooth sphere, as Aristotelians had maintained, but was uneven and rough, like the Earth. Another similarity, between Jupiter and the Earth, was furnished by Galileo's discovery of four satellites of Jupiter, similar to the Earth's single satellite.

Galileo's arguments in support of the new Copernican cosmology culminated in a clash with Catholic authorities so dramatic that it forms the foundation of the most widely held stereotype regarding the general relationship between science and religion. The conflict, however, was far from inevitable. Initially, the primary opposition to Galileo came from Aristotelian philosophers in Italian universities. At around the same time, a church official remarked that the Bible tells how to go to heaven, not how the heavens go. Wisely, the Church was not eager to enter a scientific dispute. As Augustine had suggested earlier, no cosmological doctrine should ever be made an article of faith, lest some better informed heretic exploit misguided adherence to a scientific doctrine to impugn the credibility of proper articles of faith.

Galileo's Aristotelian philosophical opponents were eager, however, to enlist the Church on their side in their battle against Galileo, and a few individual priests were induced to charge that the motion of the Earth was contrary to the Bible. Galileo, in turn, sought to win the Church to his side, and to silence potential objections to Copernican cosmology based on scripture. In an open letter of 1615, Galileo appealed to the authority of Augustine in support of the thesis that no contradiction can exist between the Bible and science when the Bible is interpreted correctly. But Galileo was out of step with the times. The Counter-Reformation, following the Council of Trent, which had met from 1545 to 1563, now demanded tight control over Church doctrine, the better to counter Protestants. Galileo also cited Augustine's warning not to make cosmological doctrine an article of faith. This was especially good advice when new scientific facts from telescopic observations were still coming in.

In 1616 Pope Paul V submitted the questions of the motion of the Earth and the stability of the sun to the official qualifiers of disputed propositions. It is not clear why he chose to act. Galileo expected the qualifiers to read the Bible metaphorically, but they read it literally and found both the motion of the Earth and the stability of the sun false and absurd in philosophy. They did not rule on the truth of Copernican cosmology in terms of its agreement with nature. The qualifiers found the motion of the Earth at least erroneous in the Catholic faith and the stability of the sun formally heretical. Here they exceeded their authority, because only the pope or a Church Council could decree a formal heresy, and Pope Paul ignored this finding. Galileo was instructed no longer to hold or defend the forbidden propositions: the motion of the Earth and the stability of the sun. The Congregation of the Index issued an edict forbidding reconciliation of Copernicanism with the Bible and assertion of literal truth for the forbidden propositions. One passage about scriptural interpretation and passages calling the Earth a star, implying that it moved like a planet, were ordered removed from Copernicus' *De revolutionibus*. Catholics could still discuss Copernican cosmology hypothetically, and little damage was done to the science.

Had Galileo at his meeting with Church officials resisted the instruction not to hold or defend the forbidden Copernican propositions, the Commissary General of the Inquisition was prepared to order him, in the presence of a notary and witnesses, not to hold, defend, or teach the propositions in any way, on pain of imprisonment. Galileo did not resist, but the Commissary General may have read his order anyway. It appears in the minutes of the meeting, unsigned and unwitnessed. Galileo may have been advised to ignore the unauthorized intervention. Subsequent rumors that Galileo had been compelled to abjure caused him to ask for and receive an affidavit stating that he was under no restriction other than the edict applying to all Catholics.

In 1623, a new pope was chosen. Urban VIII was an intellectual, admired his friend Galileo, granted him six audiences in 1624, and encouraged him to write a book on Copernican cosmology. The book, Urban hoped, would demonstrate that the Church did not interfere with the pursuit of cosmology, only with unauthorized interpretations of the Bible. The *Dialogue* on world systems was published in 1632, with Church approval. Urban, however, became angry when he found his own thoughts attributed to the Aristotelian representative in the *Dialogue,* who lost every argument. Also, the timing was unfortunate for Galileo, his book appearing in a climate of heightened suspicion, even paranoia. A Spanish cardinal had recently criticized Urban for his interference in a political struggle, and Urban had responded with a purge of pro-Spanish members of his administration, including the secretary who, coincidentally, had secured permission for printing the *Dialogue.*

Galileo was called to Rome and charged with contravening the (unsigned and unauthorized) 1616 order of the Commissary General of the Inquisition not to hold, defend, or teach the Copernican propositions in any way. Galileo produced his affidavit, signed and dated, but nonetheless was found guilty. He was compelled to abjure, curse, and detest his errors and heresies. Henceforth even hypothetical discussion of Copernican cosmology was heresy for Catholics.

The Galileo fiasco has long been a major embarrassment for the Catholic Church, and in 1978 Pope John Paul II acknowledged that Galileo's theology was sounder than that of the judges who condemned him. Galileo's battle with religious authority is the major historical source for the stereotype of an ineluctable conflict between science and religion, but the stereotype is a vast oversimplification, as most stereotypes are. This clash between cosmology and religion was avoidable.

The Mechanical universe

Copernican cosmology, though revolutionary in important respects, clung to Aristotelian circular motion, whose cause generally was attributed to God. Kepler, using Tycho Brahe's (1546–1601) observations, showed that planetary orbits are elliptical. Kepler also found several mathematical relationships, such as the proportionality of the cubes of the mean planetary distances to the squares of the periodic times. Initially he attributed planetary motion to moving souls, but within a few years was searching for a physical principle. Kepler's cosmology was strongly Christian. He was convinced that the creator had used mathematical archetypes to design the universe, and this religious belief drove his cosmological research and shaped his results, which were "a sacred sermon, a veritable hymn to God the Creator," showing "how great are His wisdom, power, and goodness."

An explanation of how the planets continue to retrace the same paths forever around the sun became a central problem of seventeenth- and eighteenth-century cosmology. Newton showed mathematically that Kepler's elliptical orbits as well as several mathematical relationships, including the proportionality of distances and times, were consequences of a universal inverse-square law of gravity. For Newton, the medium conveying action must be immaterial. The omnipresence of God, an immaterial ether, pervaded the Newtonian cosmos, offering no resistance to bodies, but moving them.

Theological implications of Newton's cosmology were criticized in 1715 in a letter to Caroline, Princess of Wales, from the philosopher and mathematician Gottfried Leibniz (1646–1716). Leibniz was a rival of Newton in the invention of the calculus, each accusing the other of plagiarism. Newton's friend Samuel Clarke answered in a letter to Caroline, which she forwarded to Leibniz. In the course of the debate Leibniz wrote five letters and Clarke five replies, which were published in 1717. Newton thought that his discoveries provided new evidence of the existence and providence of God. Irregularities in planetary motions caused by the disturbing influence of other planets would increase until the system wanted reformation. Leibniz charged that Newtonian views were contributing to a decline of natural religion in England. The implication that God occasionally intervened in the universe, much as a watchmaker has to wind up and mend his work, derogated from God's perfection. Clarke admitted that God had to intervene in the universe, but only because intervention was part of God's plan.

Eighteenth-century belief in the orderliness of the universe made determination of that order an important theological, philosophical, and scientific endeavor. William Whiston (1667–1752), Newton's successor at Cambridge University in 1703, argued that the system of the stars, the work of the creator, had a beautiful proportion, even if frail humans were ignorant of the order. In 1750 the English astronomer Thomas Wright (1711–1786) proposed a model for the Milky Way (a luminous band of light circling the heavens). Inspired by an incorrect summary of Wright's book, Immanuel Kant (1724–1804) explained the Milky Way as a disk-shaped system viewed from the Earth, which was located in the plane of the disk. Thoroughly imbued with a belief in the order and beauty of God's work, Kant went on to suggest that nebulous patches of light in the Heavens are composed of stars and are other Milky Ways, or island universes. In the absence of large telescopes and revealing observations of distant stars, philosophical and theological speculations dominated cosmology. This situation began to change after the English astronomer William Herschel (1738–1822) proposed a cosmological model rooted in observations. From the 1780s onward, the heavens, penetrated by Herschel's large telescopes, increasingly were understood as an expanded firmament of three dimensions.

The universe was also thought of as a clock, which Newtonians had argued required God's occasional reformation. But in 1786 the last major problem in celestial mechanics was solved when Pierre-Simon Laplace (1749–1827) demonstrated that the gravitational interactions of Jupiter and Saturn were self-correcting, not in need of divine intervention. Laplace also proposed a plausible mechanism for the formation of the solar system, which Newton had cited as reason for belief in divine providence, given the small likelihood that random chance could have been responsible. Reflecting the atheistic approach to nature of the French Enlightenment, Laplace attempted to replace the hypothesis of God's rule with a purely physical theory that could also explain the observed order of the universe. He was successful, at least in his own mind. According to legend, when Napoleon asked Laplace whether he had left any place for the creator, Laplace replied that he had no need of such a hypothesis.

Changing status of cosmology and religion

Cosmology and Christianity, formerly joined in Western thought, were now estranged. Furthermore, science, flush with triumphant reductions of all known phenomena of the system of the world to the universal law of gravity, was replacing religion as the source to which people turned to for inspiration, direction, and criteria of truth. The divorce of God from the physical universe may well have been inevitable with the rise of modern cosmology, however convinced were its founding fathers that they were exploring and demonstrating God's wonders.

Christian conceptions increasingly were relegated to aspects of cosmology not yet susceptible to scientific observation and analysis. They continue to play a powerful role in debates over the question of intelligent life elsewhere in the universe, in which extraterrestrials are potential evidence of God's omnipotence and benevolence. The idea of intelligent life elsewhere in the universe also challenges the conception of God as redeemer. Actual contact with extraterrestrials could well prove devastating; anthropological studies of primitive societies confident of their place in the universe find them disintegrating upon contact with an advanced society pursuing different values and ways of life.

Once theology was king of the disciplines, autonomous, the supreme principle by which all else was understood, its fundamental postulates and principles derived from divine revelation, interpreted and formulated within the tradition, and producing knowledge of ultimate value. Cosmology was a handmaiden, neither controlling fundamental knowledge nor ways of getting at it, its truths holding a lower logical status and value. The relationship between cosmology and religion is now largely reversed; both religion and politics now direct appeals for legitimacy to science.

An example is found in Georges Lemaître (1894–1966), an early proponent of an expanding universe. Lemaître was a Belgian astrophysicist and a Catholic priest, and from 1960 until his death he was president of the Pontifical Academy of Sciences. He offered a second chance for the Catholic Church to embrace and be embraced by a second Galileo. Also, in 1952, Pope Pius XII argued that modern Big Bang cosmology affirmed the notion of a transcendental creator. At the same time, Fred Hoyle (1915–2001), a leading creator and proponent of the rival steady state cosmology, was using it to further his anti-religious polemic, arguing that there was no room in his theory for a creator.

In politics, also, cosmology is appealed to for validation. Another early proponent of an expanding universe, the Russian mathematician Alexander Friedmann (1888–1925), was hailed as an example of great Soviet science, no matter that difficult conditions in revolutionary Russia in the early 1920s and Friedmann's early death from typhoid fever severely limited his scientific output. During Stalin's rule, Soviet cosmologists were expected to serve the party by providing a cosmology congruent with official party ideology.

After serving for many centuries as handmaiden to religion, science, including cosmology, now commands supreme status among intellectual disciplines. When appeals for validation and legitimacy are made, now it is more often to cosmology than to religion. Once intertwined, cosmology and religion have become estranged. Relative to cosmic time and space, human concerns approach insignificance. Much of modern cosmology has become "naturalized," shorn of its former human connections, particularly religion.

See also ARISTOTLE; AUGUSTINE; COSMOLOGY, PHYSICAL ASPECTS; EXTRATERRESTRIAL LIFE; GALILEO GALILEI, KANT, IMMANUEL; NEWTON, ISAAC; PLATO; THOMAS AQUINAS

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CREATED CO-CREATOR

A dynamic theological anthropology with the concept of the created co-creator in its core is elaborated by theologian Philip Hefner: Humans are created by God to be co-creators in the creation that God has purposefully brought into being. The word *created* thus relates to being created by God as part of the evolutionary reality (a view sometimes criticised for demeaning humans understood as *imago dei*). The word *co-creator* reflects the freedom of humans to participate in fulfilling God's purposes (a view sometimes criticised for super-elevating humans to the same level as God). The paradigm of the created co-creator is Jesus Christ who reveals that the essential reality of humans has never been outside God.

See also EVOLUTION, BIOLOGICAL; EVOLUTION, HUMAN

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CREATIO CONTINUA

The term *creatio continua* refers to God's continuing creative activity throughout the history of the universe. In a sense, most theologians accept *creatio continua,* since creation is the dependence of the whole of space-time on God. But more traditional views hold that because God is timeless and immutable, there is only one divine creative act, which originates the whole of space-time from first to last. Those who speak of *creatio continua* think of creation taking place in many successive acts, partly in response to events in time. Thus, at any particular time God's creation has not been completed, and the future is partly open, in some theological views, even for God.

See also CREATIO EX NIHILO

KEITH WARD

CREATIO EX NIHILO

Creatio ex nihilo (Latin for "creation from nothing") refers to the view that the universe, the whole of space-time, is created by a free act of God out of nothing, and not either out of some preexisting material or out of the divine substance itself. This view was widely, though not universally, accepted in the early Christian Church, and was formally defined as dogma by the fourth Lateran Council in 1215. *Creatio ex nihilo* is now almost universally accepted by Jews, Christians, and Muslims. Indian theism generally holds that the universe is substantially one with God, though it is usually still thought of as a free and unconstrained act of God.

See also CREATIO CONTINUA

KEITH WARD

CREATION

Creation refers to the idea that the whole universe is brought into being and sustained by a personal agent, God, who is beyond the universe. Since creation is an intentional act, God is usually said to envisage what will be created, and to intend that it will come into existence. Knowledge and will are thus attributes of a creator God.

Creation in various religions

Many religions have the concept of a creator God. In the late nineteenth century, the anthropologists Edward Tylor and James Frazer thought that the idea of God was in effect an early scientific hypothesis to explain why things happen as they do. They thought the hypothesis was false or superfluous, an instance of primitive science. Contemporaries, like Max Müller or the theologian Friedrich Schleiermacher, pointed to a more affective or experiential source of the idea of a creator in something like an intuition or apprehension of the infinite, or in a sense of *absolute dependence* (Schleiermacher's later term). It would not then be a scientific theory, but a primal sense of an unchanging, self-existent reality beyond the changes of the natural world.

Primal religious traditions usually contain some idea of a creator god, but often one who is remote and not particularly concerned with human affairs, delegating that to lesser gods. In the Chinese or East Asian religious stream, as represented in Daoism and Confucianism, the idea of creation is not denied, but it is not especially important. What is important is the Way of Heaven, the balance and harmony of nature itself, as reflecting in human life and society the order that obtains in the universe. The ultimate source of being, perhaps the Dao (or Way), is not seen as a personal agency. For that reason, these religious views do not have a doctrine of creation. They stress the interrelatedness and sacredness of nature, and they connect the best way of human life with insight into the natural order the universe should have. Chinese and East Asian religions tend to say, however, that questions of how the universe began or what a God might be like are both insoluble and spiritually irrelevant.

Buddhism shares with the East Asian traditions a lack of interest in, or even a rejection of, a doctrine of creation. For many Buddhists, the suffering involved in the natural world is too great to permit any thought of a good creator, and again the idea is seen as too theoretical to be of any practical use. The Buddhist way is one of disciplining the mind to overcome attachment, so that one might realize that state of wisdom, compassion, and bliss that is *nirvana*. In *Mahayana* Buddhism, there develops the idea of *bodhisattvas,* compassionate beings who help suffering beings, and who may even generate from themselves worlds in which sentient beings exist. This can come near to a doctrine of creation, but the emphasis is on a plurality of liberated beings, who may be of great compassion, knowledge, and power, but who are not creators of all reality.

In general, these religious traditions find the existence of suffering too great a problem to allow for a good creator. They find belief in a creator spiritually superfluous; their spiritual quest is for compassionate mindfulness and wisdom, and devotion to a personal god is seen as a lesser vehicle or lower path. They also find such belief too theoretical, regarding it as unprofitable speculation.

Most orthodox Indian traditions, however, have developed the idea of one supreme spiritual reality—Brahman—from which everything in the universe derives its existence. This reality can be described as *sat-cit-ananda,* or being, consciousness, and bliss. Sometimes, as in Ramanuja, the twelfth-century Indian philosopher, the one supreme reality is characterized as a supreme person. Sometimes, as in Sankara (perhaps the best-known Indian philosopher of the eighth century C.E.) it is said to be beyond personhood, though it appears as a person, and to be one undifferentiated reality of which all finite things are illusory appearances. It is a common doctrine that "all is Brahman," so that the Lord is the material cause of the universe, which is the Lord's appearance or (in Ramanuja) his "body." For Hindus in these traditions, all the gods are aspects or diverse forms of the one all-inclusive Brahman. The universe comes into being in order to work out the *karma,* the accumulated merit or demerit, of finite souls. Each universe has a finite, though vastly long, life. Then it dies, and after a period when all the potentialities of being exist in unevolved form in Brahman, they are realized again in a new universe, perhaps a repetition of the one before it. Universes come into being and pass away without beginning or end, and only Brahman remains unchanging, the one source of all.

This is a doctrine of creation, since every universe comes into being as the result of an act of knowledge, will, and desire of the Supreme Lord, who says, in the holy scriptures, the Upanishads, "May I become many" (Chandogya Upanishad, VI, ii, 3). It is usually held that each universe is necessarily what it is, and that everything in each universe is part of, or one with, Brahman. For that reason, some might prefer to call this a doctrine of *emanation,* or necessary self-manifestation of the supreme Lord. However, it is an act of will, not a sort of unconscious seepage of being. And in that self-manifestation, there are infinite souls working out their own karma, so that there is an "otherness" between each finite soul and the Supreme, even though they are ontologically one. It may be that the most obvious difference from the Abrahamic traditions—where creation is said to be a free act of the creator, and where creatures are ontologically quite distinct from the creator —is largely verbal. For in the Abrahamic faiths, freedom and necessity are often said to be compatible, so that even though the act of creation is "free," it is nonetheless an unforced yet necessary expression of the divine nature. Moreover, no creature can exist without the upholding presence of God, from which creatures can never be separated, even in hell. This doctrine of divine omnipresence is not far removed from the Indian doctrine that all things are, in a sophisticated sense, "one" with Brahman. There are divergences of doctrine, to be sure, but the conceptual differences are neither absolute nor unchangeable.

Hindu traditions deal with the problem of suffering by attributing it to the free actions of finite souls, in the sequence of rebirths, without beginning or end, which each soul experiences until it achieves release or liberation into a realm beyond suffering. So creation by a good God is ontologically necessary. God, whose essential nature is perfect intelligence and bliss, is not to blame. Moreover, Hindu traditions permit creaturely freedom and promise final bliss for all souls that choose it. And God enters into nature in many forms to help suffering beings, so that God can truly be called good.

Hindus would say that God is not spiritually superfluous, since the perfect state of intelligence and bliss is realized in one supreme being, and to know the supreme being is the greatest happiness for finite souls. Nor is God a speculative concept, since the doctrine of creation is not primarily a doctrine about the beginning of the universe (there have always been universes). It is a doctrine about the present union of all finite beings with and their dependence on the one Supreme Lord, conscious realization of which is the supreme spiritual goal.

Abrahamic faiths

In the Abrahamic faiths, mainly Judaism, Islam and Christianity, there is a shared doctrine that the universe is the creation of one supreme and perfect

God. This is usually said to be a free, nonnecessitated act of bringing into being things other than God. In Christianity, creation is through the Logos, the eternal Son, who is construed as the archetype of all creation and the uncreated image of the divine Wisdom. So the universe is seen to be contingent—it did not have to be as it is—and yet supremely rational. Some have argued that such a belief made modern science possible because it encouraged the view that nature can be understood by reason, that it is ordered and unitary, having one rational creator, yet because it is contingent, observation is necessary to discern its laws. Moreover, since nature is not divine, but it is a created object, humans can investigate it without offending the spirits. It may even be held that such investigation, at first encouraged but also impeded by the excessive authority given by the Church to Aristotle in the thirteenth to sixteenth centuries, really began to flourish only when, after 1500, that Church authority was challenged by the Reformation. So the scene was set for the rise of the natural sciences in a European culture in which reliance on close observation, insistence on critical freedom, and belief in the rational structure of nature all coalesced in one dynamic matrix.

The word *creation* has usually been used to refer to the origin of the universe, but theologically it has always been clear that it more properly refers to the relationship of every time and place to God. In this sense, when and how the universe originated is not of primary importance. Some theologians and scientists have held that if the universe can be shown to have a beginning in time, this would raise the probability that it was created. For many years it was argued that if the universe had no beginning in time, the universe would not be created, since it would necessarily always be there. Medieval philosopher and theologian Thomas Aquinas argued in Summa Theologica (1a; qq. 46, art. 2) that this view is a misunderstanding. If creation means that nothing can exist unless it is part of a world-system that God wills, it does not matter whether that system has existed forever or if it had a beginning. What the believer needs to know is not that God was needed to start the universe, but that the universe, whatever its age or size, could not exist at any moment without a self-existent creator. The doctrine of creation depends on the truth of the assertion that the material universe is not self-existent, and that it can reasonably be seen as the effect of a free act of a conscious being that is of supreme value—God.

Creation and science

All the great religious traditions formulated their views of the universe long before the rise of modern science, and they incorporate theoretical beliefs that need to be reconstructed if the findings of science are to be fully accepted. East Asian traditions in practice embody many quasi-magical practices—*Feng Shui* and astrology, for example—that would be regarded by most scientists as superstitious, and based on misunderstanding of or simple errors about how the laws of nature work. In the Indian traditions, the ideas of rebirth and of the soul as distinct from matter create tensions with evolutionary biology, neurophysiology, and genetics in particular. The Abrahamic faiths have traditionally believed in six-day creation, in a primal paradisal state without suffering or death, and in a very short history for the universe, with earth at its center, all of which is rendered obsolete by evolutionary cosmology, with its fifteen billion year history for the universe, and belief in the principle of natural selection as at least a major driving force of biological evolution.

If religious belief in creation is not primarily a speculative hypothesis, but an existential apprehension of dependence on a transcendent reality, these traditional beliefs can be revised without much difficulty. They can simply be said to express spiritual insights into the limited terms of their understanding of the universe. Their creation stories can be seen as myths, as primarily symbolic attempts to depict the human situation of alienation from a supreme transcendent reality, and the way to overcome that alienation.

It will remain important, and it is part of the drive to understanding that motivates science, to have some view, however provisional, of how the universe relates to the transcendent spiritual goal of religion. The scientific investigation of nature is important to religion because it reveals the sort of universe there is, and therefore by implication the way in which the universe could be related to a transcendent reality. If this is an evolutionary universe, in which consciousness and freedom evolve from a simple primal singularity as emergent properties of matter itself, and if this happens through the interplay of mathematically ordered laws and processes of random variation and natural selection, a number of questions need to be asked before a doctrine of creation could seem plausible. One will need to ask whether the system is well-designed, whether it shows signs of rational order or of creative freedom, whether it can be seen as purposive or directional, and whether it could be willed by a being who can be termed good.

Since humans will in all likelihood continue to give different answers to these questions, the "religious transcendent" will not always be interpreted in terms of a creator god. Many in the renouncing traditions will continue to focus on an "impersonal" state of wisdom, compassion, and bliss which has no causal role in the universe, but which can be attained by humans. In the Western Christian tradition, the element of design has been so strongly emphasized that sometimes the universe has been seen as a quasi-machine, with the creator as a cosmic clockmaker. However, some contemporary theologians, like Arthur Peacocke, have preferred to picture God as an artist, expressing the divine being in creation. Process theologians have adopted an even more organic view of the relation between the universe and its creator. In this respect they have drawn nearer to the dominant Indian traditions, which speak of the creation as "one" with the creator—meaning that the universe realizes elements of the divine nature that are in some way essential to its being what it is.

Often a contrast is drawn between Indian cyclic view of time and Semitic linear views. It is true that the Indian tradition speaks of vast repetitive cycles of creation, and the Semitic tradition speaks of this universe as having a definite beginning, end, and purpose. But it needs to be remembered that even the early Christian theologian Augustine acknowledged in Book 11 of *City of God* that God could create many universes, and for Indian thinkers each universe can be said to have the purpose of expressing the creative play of Brahman, of working out the destiny of souls, and of making liberation possible. Both these traditions agree that, however finite or infinite time may be, however repetitive or creatively new, it is wholly dependent on the intentional act of a being of supreme value that is supra-temporal. That is the heart of the idea of creation. It is widely shared between Semitic and Indian religious traditions. And while some revision of the original creation myths of these traditions is required by science, the new understanding of the cosmos that science brings may well be felt not to challenge a basic belief in creation, but to increase a sense of the wisdom, power, and infinity of the creator.

See also CREATIO CONTINUA; CREATIO EX NIHILO; DESIGN; GENESIS; LIFE, ORIGINS OF

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KEITH WARD

CREATIONISM

The meaning of the term *creationism* has varied greatly over time. In the history of Christian theology it once designated the idea that God creates a new soul for each person born, in contrast to *traducianism,* which envisions the soul as propagating in a manner similar to the way bodies propagate.

In contemporary culture, however, the term has taken on a number of substantially different meanings that need to be distinguished. For the purposes of this entry, the term *theological creationism* designates the basic belief, held by members of many religious communities, that the universe is not self-existent but is a creation; that is, the universe has being only because a self-existent creator-God gives it being. The existence of a creation is held to be dependent on the effective will of a creator not only to give it being at a beginning but also to sustain it in being from moment to moment.

But the term *creationism* usually entails more than this basic belief that the universe is a creation. The term now ordinarily designates the conviction that the creator-God of which the Bible speaks has both (1) brought the basic material of "the heavens and the earth" into being from nothing at the beginning of time, and (2) conferred specific forms on that basic material in the course of time through occasional episodes of divine intervention. Because of its strong emphasis on the need for several episodes of form-conferring supernatural action, this perspective will here be called *episodic creationism* to distinguish it from *theological creationism* as defined above. Episodic creationism has historically been called *special creationism* because of its idea that each basic kind of creature was specially created (given a specific form) to function in its environment.

Within the category of episodic creationism, however, there are numerous and vastly differing concepts of the particular manner and timetable of the creator's form-conferring interventions. Following are the basic tenets of the most common versions of these creationist portraits of God's creative action.

Young-earth episodic creationism

Young-earth episodic creationism is committed to the belief that the universe was brought into being recently (usually taken to be six thousand to ten thousand years ago) and that God's form-conferring interventions (or "acts of creation") were performed during a week of six twenty-four-hour days immediately following the beginning. The primary basis for this perspective is the belief that this portrait of the creation's formational history is the clear teaching of the Bible and that all faithful believers of biblical faiths must accept it.

Bible inerrancy. Understanding the creationists' beliefs concerning the nature and authority of the Bible is essential for understanding all forms of episodic creationism. The Bible (made up of the Hebrew Scriptures plus the New Testament writings of the early Christian era) is generally taken to be not only a trustworthy guide for faith and practice, but also an inerrant source of information on any topic that it addresses. How does the Bible come to have this remarkable character? The Bible has this quality because, inerrantists believe, the Bible is the inspired Word of God. The Bible is believed to be the product, not of human knowledge or of human experience alone, but of divine revelation of information and divine guidance in the writing of the text. As God's revelation and as the product of divine inspiration, what the Bible says can be trusted to be true and unblemished by error of any sort.

This concept of the Bible, combined with an interpretive approach that favors "the plain reading of the text," has led many to insist upon a literal interpretation of biblical narratives unless there is strong reason (derived from the Bible itself) to read it in a more figurative or artistic sense. The application of this belief to the first three chapters of Genesis has led a large proportion of the Christian community (at least in the past century) to treat the creation narratives of Genesis 1–3 as literature that is more like a documentary photograph than an artistic portrait. Consequently, Genesis 1–3 is taken to be a chronicle of God's acts of creation—a concise account of what happened and when during the first week of time. Young-earth episodic creationists read Genesis 1 as a divine revelation that God not only brought the universe into being at the beginning of time but also performed a series of form-conferring interventions over the next six days. Similarly, Genesis 6–9 is taken to be a chronicle of a catastrophic global flood event that occurred within human history, perhaps four thousand to five thousand years ago.

Creation science. Furthermore, if the Bible is the inspired Word of God, it must be true. And if it is true, then it must be open to empirical confirmation. Empirical confirmation of the recentness and episodic character of divine acts of creation is the task of a science-styled enterprise known as *creation science.* Creation science stands in the tradition of *flood geology,* which presumes that the major structural features of the earth's surface were formed as a consequence of the great flood of Noah. In both cases, selected empirical evidence is reinterpreted in such a way as to reach the conclusions that: (1) the age of the universe is not fourteen or fifteen billion years—as conventional science has concluded—but more like six thousand years; (2) new forms of life could not have evolved in the manner that most biologists believe, but must have been specially created by supernatural means; and (3) the Noachian flood can account for all of the major geological structures that characterize the surface of the earth.

There are several societies and institutions that actively promote young-earth episodic creationism, flood geology, and creation science. The Creation Research Society (CRS), for example, was founded in 1963. Its members must subscribe to a statement of belief that affirms, in the order listed:

(1) that the Bible, as the inspired Word of God, is historically and scientifically true;

(2) that all basic types of life forms were made by direct creative acts of God in six days;

(3) that the Noachian flood was a worldwide historical event: and

(4) that salvation through Jesus is necessary because of Adam and Eve's fall into sin.

The CRS has published its technical journal, the *Creation Research Society Quarterly,* since 1964 and now supports a variety of "creation-related research" projects at its Van Andel Creation Research Center in north central Arizona.

Creation science is taught in many conservative Christian schools and colleges. Graduate degrees in creation science can be earned at the Institute for Creation Research (ICR) in Santee, California. The ICR maintains an extensive resource center for books, pamphlets, research monographs, textbooks, and videos prepared for a variety of age and educational levels. Its educational outreach programs include *Back to Genesis* regional seminars, *Good Science* workshops at a variety of grade levels, creation science camps, *Case for Creation* community seminars, and creation/evolution debates in which biochemist Duane Gish defends young-earth creationism against various representatives for evolution. Programs of this sort are presented not only throughout the United States but in countries around the world.

The ICR supports research expeditions to locate the remnants of Noah's Ark on Mount Ararat in Turkey and to study catastrophic phenomena at Mount St. Helens in Washington. It sponsors both research trips and public tours in the Grand Canyon—research trips "looking for evidence to support a young-age creation interpretation of the formation and history of the Canyon," and Grand Canyon outreach tours that are "devoted to reaching pastors, teachers, professionals, and business leaders with the creation message" and designed to give its participants "an opportunity to see evidences for the Genesis Flood firsthand."

Other forms of creationism

Creationism has many variants. Three of the most prominent interpretations are old-earth episodic, progressive, and Intelligent Design creationism.

Old-earth episodic creationism. The tenets of old-earth episodic creationism are very similar to those of young-earth creationism with the exception of the timetable. The Bible is taken to be the inspired and scientifically inerrant Word of God. The formational capabilities of the created world are presumed to be inadequate to sustain biotic evolution, so that a succession of episodes of form-conferring supernatural intervention remains an essential feature of the creation's formational history, and the Noachian flood was a historical event within human history. However, the "days" of the Genesis 1 creation narrative could have been extended periods of time so that the scientifically-derived timetable for the universe's formational history may be accepted without fear of contradicting the Scriptures.

Progressive creationism. Like old-earth episodic creationism, progressive creationism is open to the contributions of science on such matters as the timetable of the creation's formational history. It also gives recognition to the idea, rooted in the Augustinian tradition, that the creation was provided by God with the formational capabilities needed to actualize the structures and life forms that God intended to appear in the course of time. Progressive creationism envisions God giving being at the beginning to the raw materials of the universe and generously providing them with formational powers. Then, in a progressive manner, the Spirit of God is thought to have stimulated and enabled these causal powers to actualize a vast array of preordained physical structures (like dry land and seas) and life forms (like plants, cattle, fish, and birds). The formational history of the creation is envisioned as a progressive and cooperative venture in which both divine and creaturely action contribute to the outcome.

Intelligent Design creationism. The Intelligent Design movement is a recent entry into this arena of creationist perspectives on the character and role of divine action in effecting the assembly of new creaturely forms—especially new life forms—in the course of time. Proponents of Intelligent Design argue that there is empirical evidence that the universe's system of natural capabilities for forming things is inadequate for assembling certain information-rich biological structures. And if the system of natural capabilities is inadequate, as Intelligent Design proponents argue, then these biological structures must have been assembled by the action of some non-natural agent, usually taken to be divine. Exactly how and when this divine action might have occurred is not specified. Little or no appeal is made to the biblical text to support the theological implications of this concept.

See also CREATION; CREATION SCIENCE; DESIGN; DESIGN ARGUMENT; DIVINE ACTION; GOD; INTELLIGENT DESIGN; SCOPES TRIAL; SCRIPTURAL INTERPRETATION

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CREATION SCIENCE

Creation science is a science-styled activity dedicated to the goal of providing observational, experimental, and theoretical support for the basic tenets of young-earth episodic creationism. These tenets are: (1) that the world was brought into being recently (a few thousand years ago); and (2) that the basic types of physical structures (like the sun, moon, and stars) and the basic kinds of living creatures were formed by episodes of supernatural intervention during the first week after the beginning. On the basis of its interpretation of selected empirical data, creation science argues that the universe cannot be as old as the natural sciences have concluded, and that the full array of life forms could not possibly be the outcome of uninterrupted evolutionary development.

See also CREATIONISM; DESIGN; DESIGN ARGUMENT; INTELLIGENT DESIGN; SCOPES TRIAL

HOWARD J. VAN TILL

CRITICAL REALISM

Critical realism is a philosophical view of knowledge. On the one hand it holds that it is possible to acquire knowledge about the external world as it really is, independently of the human mind or subjectivity. That is why it is called *realism*. On the other hand it rejects the view of *naïve realism* that the external world is as it is perceived. Recognizing that perception is a function of, and thus fundamentally marked by, the human mind, it holds that one can only acquire knowledge of the external world by critical reflection on perception and its world. That is why it is called *critical*.

History

Critical realism arose in German philosophy in the late nineteenth and early twentieth centuries as a reaction to idealistic and phenomenalist types of philosophy. German critical realists took account of Immanuel Kant's (1724–1804) view of the subjectivity of knowledge but denied that this precludes access to "things-in-itself." In American philosophy, critical realism designates a movement initiated by Roy Wood Sellars (1880–1973) in 1916. It purported to integrate insights of both idealism and new realism, which was a naïve realist reaction to idealism. Through the work of Wilfrid Sellars (1912–1989), Roy Wood Sellars's son, critical realism influenced scientific realism, which arose in the 1950s in opposition to positivistic phenomenalism. Scientific realism basically claims that mature scientific theories are approximately true (in the sense of corresponding to the external world) and that their postulated central entities really exist.

The term *critical realism* was introduced into the dialogue between science and theology in 1966 by Ian Barbour. Barbour used the term to cover both scientific realism and a theological realism that takes seriously the cognitive claims of religion, that is, religion's claims to convey knowledge of a mind-independent divine reality. Subsequently Barbour pointed to the cognitive role of metaphors, models, and paradigms in scientific as well as religious language. His ideas were later assimilated and elaborated by Arthur Peacocke, John Polkinghorne, J. Wentzel van Huyssteen, and others. Actually, critical realism has been the dominant epistemology in the dialogue between science and theology for several decades. However, since the 1990s the transfer of critical realism from science to theology has increasingly been disputed, mainly on the ground that it does not, or does not sufficiently, do justice to the specific nature of theology.

Analysis

On closer inspection, critical realism as a view of scientific and theological knowledge comprises three theses:

(1) *Metaphysical realism,* which holds that there exists a mind-independent reality. In scientific realism this reality is the material world; in theological realism this reality is the material world and also, primarily, God.

(2) *Semantic realism,* which holds that science and theology contain propositions, that is statements capable of being true or false in the sense of correspondence to the reality to which they refer. In scientific realism the focus is on propositions about unobservable entities; in theological realism the focus is on propositions about God.

(3) *Epistemic realism,* which holds that it is possible to put forward propositions that are approximately true, that some propositions actually are approximately true, and that belief in their approximate truth can be justified. In scientific realism this applies primarily to theories and theoretical propositions about unobservable entities; in theology it applies to propositions and theories about God.

The first thesis distinguishes critical realism from idealism and positivism, but also from Hilary Putnam's (b. 1926) "internal realism," which defines reality as a function of human conceptualization of the world. The second thesis distinguishes scientific realism from an instrumentalism that regards statements about unobservable entities as useful fictions without propositional content. Similarly, it distinguishes theological critical realism from the Wittgenstein-inspired view of religious language as mere expression or recommendation of a way of life. The third thesis distinguishes critical realism from a skepticism that affirms the first and second theses but denies that it is possible to acquire justified approximate knowledge of a mind-independent reality. On the other hand, the qualification "approximate" entails a dissociation from the naïve realist claim that reality is as it is perceived.

Discussion

The main arguments in favour of scientific realism are:

(1) The fact that observation and experiments again and again compel scientists to change their prior ideas points to a substantive external input into science.

(2) The predictive success of mature theories can only (or at least best) be explained by the view that the processes, structures, and entities postulated by those theories approximate reality.

(3) The effectiveness of science-based technology can only (best) be explained by the view that mature scientific theories match nature to a substantive degree.

The main arguments against scientific realism are:

(1) Scientific theories are underdetermined by the empirical data; that is, the same data permit different theories that explain them. Therefore, empirical success is not a sufficient reason to assume that a theory is true.

(2) The history of science abounds with once empirically succesful theories that are now abandoned (e.g., a whole cluster of nineteenth-century theories assuming the existence of ether as a central entity). Therefore, empirical success is not a sufficient reason to assume that a theory is true.

(3) Scientific realism claims that those theories that offer the best explanation of the data are (approximately) true. This claim is thought to be supported by the argument that realism is the best explanation of the predictive success of science. However, this argument is viciously circular because it employs the kind of reasoning the validity of which it has to vindicate.

The main arguments in favour of transferring critical realism from science to theology are:

(1) Like science, theology makes cognitive claims.

(2) Science seeks to explain sense-experience with reference to the natural world, just as theology seeks, or should seek, to explain religious experience with reference to a divine reality.

(3) Both science and theology employ metaphors and models as approximative descriptions of an external reality.

The main arguments against transferring critical realism from science to theology are:

(1) Religious language has an expressive or recommending function, rather than a cognitive one. Therefore, theology should not be concerned with an external divine reality.

(2) Theology concerns itself with God, who is wholly different from the natural world, which is the subject matter of science.

(3) Theology cannot refer to a similar predictive success as science. Therefore, theology lacks a counterpart of the principal reason for a realistic view of science.

In evaluating a critical realist view of science and theology it may be useful to realize that the discussion of scientific realism has focused on scientific theories, especially on unobservable theoretical entities. One should not forget, however, that science is more than theories. It comprises also a wealth of observation statements and statements of primary relations, such as the statement that the specific gravity of lead is approximately 11.4. Although such statements are not theory-free, they will often have a realist plausibility that will even be acknowledged by most instrumentalists. As a consequence, a realist understanding of large parts of science seems to be a plausible option. However, scientific realism can hardly be a global view of science. Realistic plausibility has in principle to be established for each proposition and theory in particular. It would seem that this specification lessens the force of those arguments against scientific realism that aim at a global view.

As for the plausibility of transferring critical realism from science to theology, it should be realized that there are great differences between theology and science. As a reflection on religion, theology is primarily concerned with the question of the meaning of life, which implies that theology, unlike science, has an existential dimension. This does not, however, alter the fact that theological statements, insofar as they are propositions about God, make cognitive claims. Hence, critical realism is at least a logically possible view of theological propositions. But since God is not accessible to sense experience and experimental control, critical realism can hardly have the same rational plausibility for theology as for science. It would seem that a critical realist view of theology, or rather of particular theological propositions about God, is only a viable option within the context of faith.

See also COHERENTISM; EPISTEMOLOGY; KANT, IMMANUEL; REALISM

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KEES VAN KOOTEN NIEKERK

CULTURE, ORIGINS OF

The dawn of culture may be the single most important development in human evolution. Sometimes people find their dependence on culture frustrating, but overall it is far more an enabler than a limitation. The human ability to think would be grossly constrained without language, however often people find themselves at a loss for words. Humans would not be human without culture to mediate their relationships with the environment, with other humans, with spirits and deities, and with abstract or imagined worlds like mathematics and the future.

Despite many suggestions, the definition E. B. Tylor used when introducing the term *culture* to anthropology is still popular: “that complex whole which includes knowledge, belief, art, morals, custom and any other capabilities and habits acquired by man as a member of society” (p. 1). Lee Cronk and others have preferred not to include behavior, seeing culture as socially transmitted information or, as Clifford Geertz, puts it, patterns for behavior, not patterns of behavior.

Most traditional peoples have explanations of cultural origins, myths about the first fire or the gift of corn. Intensifying this quest for knowledge of cultural origins with new information about cultures all over the world, Enlightenment philosophers tried to imagine an original “state of nature.” The seventeenth-century philosopher Thomas Hobbes envisioned perpetual war, concluding that individuals would gladly give up unbounded liberty for the protection of government. The eighteenth-century philosopher Jean-Jacques Rousseau’s vision was a celebration of freedom, equality, and the unfettered, uncorrupted individual. But whatever life can or should be it is clear that for humans the “natural” state is within society, enveloped by culture.

What is known about the prehistory of cultural origins is easily outlined. The following scenario is primarily derived from Richard Klein, with insights from Merlin Donald on the interrelation of culture and cognition. The data suggest brief periods of rapid transition, which is one reason many paleoanthropologists prefer the Eldredge-Gould punctuated-equilibrium model of evolution to neo-Darwinism.

The appearance of flaked stone tools 2.5 million years ago, the earliest known evidence for culture, coincides with the appearance of the first people with brains proportionally larger than apes. This is Donald’s *mimetic stage* of cognitive development, representing emergence of the ability to mime, to imitate, and to re-enact events. The appearance of the first people with fully human body proportions about 1.7 million years ago was probably coincident with invention of the hand axe and the first hominid movement out of Africa.

A rapid increase in brain size about six hundred thousand years ago correlates with developments in lithic technology and the appearance of archaic *Homo sapiens.* This development corresponds to Donald’s *mythic stage,* in which the increased pace of technological innovation is evidence of true human language. The timing of language, however, remains deeply contentious.

The “creative explosion” or “Big-Bang” of human cultural development occurred about forty-five to fifty thousand years ago with the appearance of the fully human creative use and manipulation of culture. This development corresponds to

Donald's *theoretic* or *modern culture* stage, which was marked by the ability to enhance what is possible with the brain alone through externalization of memory.

When did human culture first appear?

One could legitimately place culture's origins at any of these stages. One could even place the origin of culture earlier, since stone tools may not be the first products of culturally based behavior; this would place the origins of culture well before the appearance of the human species. As recently as the 1970s it was a virtual truism that only humans had culture. But by 1973 Jane Goodall had recorded thirteen forms of tool use and eight social activities distinguishing the chimpanzees of Gombe in Tanzania from those at other study sites. Goodall proposed a cultural origin for these variations, and recent work has amply reinforced that view. Andrew Whiten and Christophe Boesch argue that chimpanzees display not only individual cultural traits but sets of distinctive behaviors that can be thought of as, for example, "Gombe culture" or "Teï culture."

Nonhuman culture or proto-culture is widespread among primates. Indeed, John Bonner provides many examples of animals, including birds, that are capable of behavioral transfer of information. But human culture is cumulative and makes use of symbolism. Human culture is also uniquely creative, flexible, diverse, and capable of both rapid change and remarkable stasis, even in changing environments. The "creative explosion" or "Big Bang" of human development likely represents the move from proto-culture to a truly human symbolic and cumulative culture. Human culture has become a newly emergent property of life that no longer needs to wait generations for genetic changes but can rapidly effect behavioral changes.

Sources, causes, and correlates of culture

What follows is a sampling of major contemporary theories of cultural origins, beginning with models of cultural evolution. Though not strictly theories of origins, they are essential for understanding how culture works and how cultural diversity came about.

For sociobiologists, natural selection is central, controlling even the details of human thought. Cultural origins and contemporary diversity are based on genetic differences in human populations. A recent variant, evolutionary psychology, accepts the criticism that genetic change cannot even remotely keep pace with cultural change, but retains the view that what people believe and do is based on genetic adaptations. Thus, how contemporary humans think is constrained by genes selected for the ways of life of earlier humans. Contemporary humans are basically hunter-gatherers ripped from the savanna, with mind ill suited and ill at ease with city life—a modern "expulsion from the garden" myth that attributes deep human dilemmas to gene-environment mismatch. With great clarity Holmes Rolston presents many important reasons why strong versions of these theories do not succeed. Early humans lived under varying conditions, not a single environment of adaptedness, and behaviors are not directly programmed by genes. Further, ideas can be transmitted to unrelated, even unknown, individuals.

Some scholars prefer to understand culture as radically separate from biology. This is the traditional anthropological perspective; Alfred Kroeber's influential "superorganic" notion views culture almost as having a life of its own, molding each individual far more than individuals mold culture. Memetics proposes a new kind of replicator, the *meme* an element of culture passed on by non-genetic means. Culture is a meme's way of replicating itself; beliefs and opinions are survival tricks memes use for self-perpetuation. Strict forms of these theories, however, would only work if cultures were composed of genuinely distinguishable units. In addition, the transmission processes (analogies with disease organisms abound) presume an unreasonable passivity in human communication.

Recognizing that human lives are influenced both by genes and by culturally transmitted ideas, *gene-culture co-evolution* or *dual inheritance* models ask how these influences relate. Importantly, it can be acknowledged that beliefs and behaviors are selected and transmitted by various means; it is only the overall mix that must be adaptive. William Durham demonstrates in, for example, his lactose tolerance case study that culture can be a causal force in human genetic evolution.

Sexual selection. Geoffrey Miller believes much of human culture (e.g., the arts, ritual, ideology) makes more sense as courtship display than as survival adaptation. Mate choice selects for indicators of fitness, which can explain interesting features of humanity. For example, because courtship displays need only indicate fitness, belief systems could develop that "work" even though they do not accurately depict the world.

Causal events, triggers, and mechanisms.

Another approach is to isolate one or a few variables as causes for the development of culture. Distinguishing human labor from animal behavior, the nineteenth-century social scientist Friedrich Engels proposed production as the primary factor, while Randall White and others suggest a trend toward increased group size. Social groups comprised of more people required more complicated social organization than do small, family-size groups, creating demands on communication. Michael Pfieffer has proposed an environmental change as the causal event. Rick Potts argues that the human innovation was to develop flexible cognitive abilities to face regular climate changes. Richard Klein argues that a single genetic mutation completed the modern brain, triggering the human capacity for culture. There is growing reason to believe genes are only indirectly connected to phenotype, yet there is also evidence that one change can make a dramatic difference. Michael Tomasello believes that a new form of social cognition, the ability to see other humans as intentional beings, triggered cognitive-cultural co-evolution.

Cooperation, altruism, and love. Elliott Sober and David Sloan Wilson argue in *Unto Others* (1998) that self-giving behaviors may benefit a group enough to compensate evolutionarily for any harm caused to individuals within the group. And Adrienne Zihlman points to the great importance of mother-infant interaction in the development of primate sociality. This emotional closeness and communication prepares individuals for culturally based cooperation and self-giving better than if society is, as alternative interpretations suggest, an endless power struggle. For Catherine Key and Leslie Aiello as well, cooperation defines humanity.

Blood relations. The developing human brain came with great costs especially to females whose reproductive strategy would have emphasized helping offspring reach maturity. The primate male strategy would have been to fertilize as many females as possible. Culture began, Chris Knight argues, when females obtained male energetic investment by confusing the males about the female's fertility state, thus tricking the males into sticking around. Menstruation is an obvious clue to pending fertility, and males, with only one thing on their minds, would turn away from nursing females to more fertile females just when most needed. Solution? Females could paint themselves red and all would appear equally fertile.

Relevance to science-religion dialogue

Whatever else one may conclude, Knight's proposal suggests that human agency and purpose are part of what needs to be explained. From this brief survey of theories of cultural origins, it is clear that human thought is probably not genetically determined in detail. And because cultural origins and transmission are quasi-independent of genetics, one can ask of an idea not just whether it spreads genes but how well it describes the world. Humans regularly create new ideas and pass them on nongenetically. One implication is that, to the extent values and virtues are culturally based, they do not need to be explained by natural selection on genes.

It would still be valuable to know whether altruism and true other-regarding love can arise by natural selection. John Polkinghorne and his colleagues have argued that love may be a deep feature of the universe itself, not just of human cultural beliefs. The study of human cultural origins may have something to contribute to this debate.

Understanding human cultural origins is also important for the science-religion dialogue because it raises important issues for understanding each of these elements of culture. For example, to the extent that human culture and behavior are only loosely tied to our genetic variation and to our evolutionary history, the religious and scientific quests could do more to put us in touch with a reality outside of our individual subjective selves than some existing models of human nature allow. As another example, religion and ethics are very likely human universals, originating early in human cultural evolution. If love is a significant feature of reality and to the extent that human culture evolved out of cooperation and self-giving as Zilman suggests, religion and ethics could be more central to and indicative of human culture than we usually allow. Their origins could, in turn, be important in cultural origins. Could it be that the origins of the human religious, spiritual and ethical sense was an essential piece in the puzzle of the origins of human culture and so of humanity itself?

See also ALTRUISM; ANTHROPOLOGY; ART, ORIGINS OF; EVOLUTIONARY PSYCHOLOGY; EVOLUTION, BIOCULTURAL; MEMES; PALEOANTHROPOLOGY; PUNCTUATED EQUILIBRIUM; SOCIOBIOLOGY

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PAUL K. WASON

CYBERNETICS

The term *cybernetics* is derived from the Greek word *kybernetes* (steersman). The term was introduced in 1948 by the mathematician Norbert Wiener (1894–1964) to describe how systems of information and control function in animals and machines (steersmanship). Cybernetics is inherently interdisciplinary; it is related to systems theory, chaos theory, and complexity theory, as well as artificial intelligence, neural networks, and adaptive systems. Cybernetics was formulated by thinkers such as Wiener, Ludwig von Bertalanffy (1901–1972), W. Ross Ashby (1903-1972), and Heinz von Foerster (1911–). It developed as a consequence of multidisciplinary conversations among thinkers from a variety of disciplines, including economics, psychiatry, life sciences, sociology, anthropology, engineering, chemistry, philosophy, and mathematics. Cybernetics contributed greatly to the development of information theory, artificial intelligence, artificial life, and it foresaw much of the work in robotics and autonomous agents (hence the term *cyborg* for robot).

After control engineering and computer science became independent disciplines, some cyberneticists felt that more attention needed to be paid to a system's autonomy, self-organization, and cognition, and the role of the observer in modeling the system. This approach became known as *second-order cybernetics* in the early 1970s. Second-order cybernetics emphasizes the system as an agent in its own right and investigates how observers construct models of the systems with which they interact. At times, second-order cybernetics has resulted in the formulation of philosophical approaches that, according to some critics, are in danger of losing touch with concrete phenomena.

Cybernetics moves beyond Newtonian linear physics to describe and control complex systems of mutual causalities and nonlinear time sequences involving feedback loops. It seeks to develop general theories of communication within complex artificial and natural systems. Applications of cybernetic research are widespread and can be found in computer science, politics, education, ecology, psychology, management, and other disciplines. Cybernetics has not become established as an autonomous discipline because of the difficulty of maintaining coherence among some of its more specialized forms and spin-offs. There are thus few research or academic departments devoted to it.

Because of the diffuse interdisciplinarity of cybernetics, theological, religious, and philosophical concerns and engagements are multiple. Some conversations concern the social and economic impact of computer networks, such as the internet, on culture and nature. Others concern the development of artificial life and artificial intelligence and its impact on how human intelligence and life is understood. Other theological and philosophical concerns of cybernetics include the shape of divine activity in the world, the "constructed" nature of knowledge and of ethical values, the boundaries between bodies and machines and the implications for creation, the promises of salvific technology, and a tendency to strive for a metanarrative or grand unifying theory.

See also ARTIFICIAL INTELLIGENCE; ARTIFICIAL LIFE; CHAOS THEORY; COMPLEXITY; CYBORG; PROCESS THOUGHT; SYSTEMS THEORY

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MARION GRAU

CYBORG

Cyborgs are human beings who have technical parts attached to their bodies on a semipermanent or permanent basis to enhance their capabilities. The term *cyborg* was first used in science fiction literature and refers to a convergence of human and robotic life forms; it can also be used to describe someone enmeshed in the World Wide Web. In Artificial Intelligence, the term is used to define people who wear ubiquitous computer parts (chips, storage, processors, etc.) hidden in clothes, as well as people with special glasses that enable them to be constantly online. Often the term raises fears as cyborgs challenge the boundaries of the human-machine interaction and thus our human uniqueness.

See also ARTIFICIAL INTELLIGENCE; ARTIFICIAL LIFE; CYBERNETICS; TECHNOLOGY

ANNE FOERST

CYCLICAL UNIVERSE

Within closed universe models there exists the possibility that a final Big Crunch may not be the end of the universe. It has been speculated that perhaps some mechanism exists at such infinite density that would trigger another Big Bang. Hence the Big Crunch really becomes the "Big Bounce," with the universe recycling itself for infinity. Also known as an oscillating or reprocessing universe, this idea has ancient parallels, both in the Hindu Vedas and in ancient Greece, and was even taken up by the early Christian theologian Origen (185–254 C.E.). The mechanism of a cyclical universe is considered beyond the reach of human understanding, however, because the laws of physics break down at the space-time singularity of the rebound. For this reason, and perhaps also due to a certain philosophical prejudice against the notion of a cyclical universe, the idea has never been popular in modern scientific cosmology.

See also BIG BANG THEORY; BIG CRUNCH THEORY; COSMOLOGY, PHYSICAL ASPECTS; COSMOLOGY, RELIGIOUS AND PHILOSOPHICAL ASPECTS; SINGULARITY

MARK WORTHING

D

DAO

The root meaning of the Chinese word *Dao* is “path” or “way.” It is more commonly known in English by the older transliteration *Tao* and is one of the few Chinese words that have been adopted into the English language. This is largely due to the broad appeal of an ancient Chinese text (c. fourth century B.C.E.) known as the *Daode jing* (or *Tao-te-ching*), which, it is said, is the most widely translated book in the world after the Bible.

During the period in Chinese history known as the Warring States (481–220 B.C.E.) the Zhou dynasty empire had disintegrated into several smaller states governed by rival feudal lords. This chaotic state of affairs led intellectuals to ask “Where is the Dao?” By this they meant: What path should leaders follow to bring harmony and stability to the country? Confucians said that the way lay in restoring ancient moral and ritual codes. Legalists said that the way lay in imposing by force a single language and legal system upon the country. Daoists, whose names are not known, compiled the *Daode jing,* a collection of terse aphorisms, which states that the way that humans should follow is precisely the same “Way” that governs the operation of nature. This Way is “self-so” or “spontaneous,” that is, it is naturally self-generating and cannot be artificially engineered by human intelligence or culture. To give a modern analogy, in nature acorns marvelously grow into oak trees and the various species live in an overall state of organic harmony. Nobody tells acorns or the various species what to do, yet somehow they develop their innate potential (*de*) and entirely of their own accord follow a path (*dao*) that leads to a state of maximal perfection and harmony. The Dao may thus be understood as the wellspring of natural creativity that brings everything in the world into an organic, harmonious existence. In this respect there are many broad parallels with the process philosophy of Alfred North Whitehead (1861–1947).

In his investigations into science and civilization in China, the British biochemist Joseph Needham (1900–1995) concluded that Daoists had a natural affinity with what is now called “science,” since to investigate the Way, Daoists had to pay close attention to the operation of things in nature. The difference is that science holds nature to be in principle explainable, whereas Daoists generally understand the Dao to be fundamentally mysterious and beyond human understanding.

This wondrous aspect of the Dao led to a mystical reverence for nature’s marvelous capacity for self-transformation: Who could possibly have imagined that an acorn would grow into an oak tree? Some Daoists, such as Ge Hong (283–343 C.E.), became alchemists and aimed to capture for themselves the extraordinary power for change that is pregnant within nature, and to reverse it to create an elixir of immortality. Other Daoists revered this mystical aspect of the Dao in the form of gods and spirits who have power over human life and death. Still others cultivated this Dao within themselves through meditation and *Qi*-energy practices. All aimed through their various methods to attain the Way for themselves.

See also CHINESE RELIGIONS AND SCIENCE; CHINESE RELIGIONS, DAOISM AND SCIENCE IN CHINA; CHINESE RELIGIONS, HISTORY OF SCIENCE AND RELIGION IN CHINA; PROCESS THOUGHT; WHITEHEAD, ALFRED NORTH

JAMES MILLER

DAOISM

See CHINESE RELIGIONS, DAOISM AND SCIENCE IN CHINA

DARWIN, CHARLES

Author of the *Origin of Species* (1859) and the *Descent of Man* (1871), Charles Darwin (1809–1882) famously challenged the popular belief that every species had been separately and immediately created by divine fiat. His theory of evolution by natural selection was based on what he considered an empirical fact: the presence of variation among members of every species. Darwin's powerful argument was that, in competition for limited resources, those variants having characteristics that favored them in their struggle would tend to be preserved and produce more offspring than those less advantaged. Over many generations the gradual accumulation of advantageous variations would lead to the emergence of a new species markedly different from its progenitor. Applied to humankind the argument was particularly contentious for the continuity it affirmed between animals and humans, and because the idea of species transformation was often associated with political radicalism and materialism. Darwin himself recalled that admitting the mutability of species had been like confessing to murder.

Providing a naturalistic account of species production and then of human evolution, Darwin risked offending the piety of those, including his own wife Emma Wedgwood, who wished to give the moral sense a transcendental significance. If humans had evolved from humbler species could humans be said to be made in the image of God? Was it possible to speak of an immortal soul? What remained of the argument for design, which in Christian natural theology had often presupposed the perfect adaptation of organic structures to the needs of the organism that possessed them?

Darwin was not the atheist vilified in ultraconservative religious literature, but he did become increasingly agnostic. Attacked in the name of religious orthodoxy, he found it "ludicrous" that he had once intended to become a clergyman. This was a reference to his Cambridge education, which had followed an abortive preparation in Edinburgh for a medical career. At Cambridge, the young Darwin encountered divines such as John Henslow and Adam Sedgwick who combined scientific enthusiasm with reverence for nature as a work of creation. In Edinburgh he had moved in free-thinking circles and had been introduced to the evolutionary theory of the French naturalist Jean-Baptiste Lamarck. Darwin also knew that his grandfather Erasmus Darwin had proposed organic transformation, but Charles Darwin was not yet a convert to such ideas. On leaving Cambridge his destiny would be to find ways of explaining the appearance of design in such intricate mechanisms as the human eye without recourse to the divine "Contriver" celebrated by the theologian and philosopher William Paley in his *Natural Theology* (1802).

Darwin's research

This destiny was shaped by a five-year voyage on which Darwin embarked in December 1831 as companion to Robert Fitzroy, captain of HMS *Beagle*. The ship was sailing for South America, enabling Darwin to enlarge his horizons as a naturalist and geologist. Having been captivated by the travelogues of Alexander von Humboldt he soon luxuriated in the rain forests of Brazil. As Adrian Desmond and James Moore have observed, their sublimity afforded a surrogate religious experience: "twiners entwining twiners, beautiful lepidoptera, silence, hosanna" (p. 122). Thoughts of a Christian ministry gradually receded as Darwin was enchanted by the study of nature, delighted by the discovery of fossil bones, staggered by the number of species that had become extinct. He was intrigued by resemblances between lost and living forms, by tantalizing patterns in the distribution of flora and fauna, and by disruptive natural forces. Entering the city of Concepción in Chile he found the cathedral shattered by an earthquake. At the Southern tip of South America natives of the Tierra del Fuego were struggling to survive in one of the most inhospitable regions on Earth. The world was perhaps not the "happy world" of

Paley's English garden. Even before reading economist Thomas Malthus's *Essay on Population* in September 1838, Darwin had been "well prepared" to appreciate the struggle for existence that Malthus's arithmetic on reproductive fecundity convinced him was inexorable.

Of his visit to the Galapagos Islands it is often said that Darwin recognized that each island had its own distinctive species, eventually concluding that the different finches, for example, had diverged from a mainland ancestor, molded by nature to occupy different niches. But there was no such "Eureka" moment. Darwin had muddled his finch specimens from various islands and it was not until March 1837, following his return to England, that the ornithologist John Gould broke the exciting news that three forms of mockingbird, from different islands, were genuinely different species. Gould identified fourteen species of finch from Darwin's specimens. The enthralling question was why so many similar species lived in such proximity, but Darwin was unable to prove that the geographical isolation of each island had been responsible for the proliferation.

Darwin's earliest speculations on evolutionary change preceded his reading of Malthus. They show him playing with the idea that nature employs bisexual reproduction as a way of introducing variation into each new generation, so permitting continuing adaptation to changing conditions of existence. Darwin flirted with, but quickly rejected, the possibility of sudden mutation as a source of evolutionary change. As with the naturalist Alfred Russel Wallace later, it was when reading Malthus that the penny finally dropped and a theory of natural selection took shape.

The metaphor of "natural selection" allowed Darwin to exploit a simple analogy. Domestic animals and birds showed a degree of plasticity as breeders chose which specimens to mate when selecting for characteristics they wished to accentuate. Darwin crossed social barriers in fraternizing with pigeon fanciers and he emphasized the diversity of form ultimately derived from the common rock pigeon. Even a trained ornithologist, he argued, would be tempted to think that the pouter, runt, and fantail were not merely different varieties but different species. If, through human "selection," such effects could be produced, might not nature achieve much more in the millions of years at its disposal? For insight into the age of the Earth and for an emphasis on the incompleteness of the fossil record, which would help him to explain the absence of transitional forms in the fossil record, Darwin was indebted to the geologist Charles Lyell.

Darwin's view of religion

Did the metaphor of "selection" imply a divine selector in the management of the evolutionary process? Some of Darwin's contemporaries believed so. Darwin's own emphasis, however, was on the interplay of unconscious forces. Without denying a creator on whom the existence of everything ultimately depended, Darwin rejected the kind of deity who might be micromanaging the process. Rejecting the argument for design as formulated by Paley, Darwin's extension of natural law to explain how new species had arisen did not preclude a transcendent legislator. In his first transmutation notebook, he wrote of a "Creator who creates through laws," one who had "impressed" certain laws on nature, as a consequence of which beautiful organic forms had evolved. Darwin resembled earlier deists, admitting the existence of a creator but doubting there had been divine revelation or intervention

In certain respects his science corroded a residual faith. The more people know of the fixed laws of nature, he wrote in his *Autobiography,* "the more incredible do miracles become" (p. 86). As his wife recognized, the questioning mentality demanded of a scientist could induce skepticism. Debating the question whether evolution was under divine control, Darwin stressed the elements of randomness in the process. His conclusion was that the variations on which natural selection worked appeared without a prospective use in mind. The presence of so much pain and suffering also affected Darwin deeply. This was difficult to square with belief in a beneficent deity, but was consistent with his hypothesis of natural selection and with what in the first full sketch of his theory (1842) he called the "concealed war of nature."

To ascribe Darwin's agnosticism to his science would, however, be simplistic. During the *Beagle* voyage he was already asking himself whether an intuitive sense of God was universal among humankind, concluding it was absent among Fuegians and native Australians. Some Christian teaching he found morally repugnant. Aware of high moral standards among the freethinkers he met in the circle of the English writer and social reformer Harriet Martineau, he declared in his *Autobiography* that the idea of eternal damnation for those outside the fold was a "damnable doctrine" (p. 87). Although opinions differ as to when he finally renounced Christianity, the death early in 1851 of his young daughter Annie produced a crisis in which belief in a beneficent God became unsustainable. His agnosticism was to be peculiar since he retained the conviction that the universe as a whole could not be the result of chance. But so nuanced was his thinking that he came to mistrust his own conviction. If the human mind was itself the product of evolution, what guarantee was there that it could be trusted when engaging such metaphysical issues?

Religious responses to Darwin's science

Religious responses to Darwin's science have varied enormously. From 1859 until the 1930s, when a powerful new synthesis of genetics and Darwinian theory appeared, the controversial status of natural selection left plenty of scope for supplementary or alternative mechanisms for evolution in which divine control was affirmed. Strictly speaking, as the biologist Thomas Henry Huxley insisted, Darwinism had no implications for the central tenets of theism. Huxley even conceded that it was still possible to assert design in an original cosmic state from which all had developed through natural processes. Modern atheists and materialists, by contrast, frequently stress the apparently directionless aspects of biological evolution, weaving them into a completely secular and naturalistic world view.

Within the Christian churches the theory of evolution, not surprisingly, continues to be a divisive issue compounding the problems posed by historical criticism of the Bible. In some religious communities it has become the symbol of secular and liberalizing values and is still vehemently resisted. Yet religious writers have also appropriated Darwin's theory for constructive purposes, as did one of Darwin's early converts, Charles Kingsley, who concluded that a deity who could make all things make themselves exhibited greater wisdom than one who simply made things. Might a unified process of evolution testify more eloquently to a single creator than piecemeal creation? Darwin's American correspondent Asa Gray, a botanist, even suggested the theory might assist the theologians with their greatest difficulty—the problem of suffering. If competition and struggle were the prerequisites of a creative process, without them there could not have been the evolutionary development that had culminated in human intelligence and responsiveness. Darwin himself had toyed with the idea that a deity who had created the *possibility* for humans to evolve might be considered less directly responsible for the uglier facets of nature that had also been possible in such a world. Sophisticated theologians have invoked the Darwinian theory to illuminate what they see as God's self-limitation rather than coercive agency. Others have seen in evolution evidence of divine immanence and participation in the world. It was the view of nineteenth-century Oxford theologian Aubrey Moore that, under the guise of a foe, Darwin had done the work of a friend, destroying infantile images of a conjuring god who was inactive except when intervening.

See also CREATIONISM; CREATION SCIENCE; DEISM; DESIGN; DESIGN ARGUMENT; DIVINE ACTION; EVOLUTION; EVOLUTION, BIOCULTURAL; EVOLUTION, BIOLOGICAL; EVOLUTION, HUMAN; EVOLUTION, THEOLOGY OF; GENETICS; IMMANENCE; INTELLIGENT DESIGN; REVELATION; SCOPES TRIAL

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JOHN HEDLEY BROOKE

DARWINISM

See DARWIN, CHARLES; EVOLUTION, BIOLOGICAL; EVOLUTION, HUMAN; NEO-DARWINISM

DARWINISM, NEO

See NEO-DARWINISM

DARWINISM, NEURAL

See NEURAL DARWINISM

DARWINISM, SOCIAL

See EVOLUTION, BIOCULTURAL; SOCIOBIOLOGY

DEATH

Within the popular Western Judeo-Christian tradition, death has usually been understood to be a consequence of original sin. This has, of course, not been a scientifically informed belief. And where theology has been in conversation with science on this point, or when theology is indirectly informed by a growing ecological consciousness, natural death in and of itself is increasingly seen as a natural piece of the creation that God called good.

Western religious perspectives

The growing perspective that death according to natural processes is not necessarily a consequence of sin would cohere with the early Christian tradition, as well as with Eastern Orthodox theology. The second-century Christian theologian Irenaeus, for example, emphasized how the first parents, as described in one of the Genesis accounts, were driven out of paradise so that they would not eat of the tree of life after they had sinned. Their being secured from that temptation by expulsion into a hard life was thus a gift—for who would want to live eternally estranged from God?—and presupposes that they were mortal beings. Indeed, death was already part of the natural order designed by God. Eastern Orthodoxy reiterates this anthropology with its emphasis on the incarnation as more a leading of humanity into the next aspect of

God's creative work than of rescue from sin and evil; the need for Christ to redeem the creation from the new exigency of sin was, as it were, added to the original agenda of leading the creation into the new age.

Western theology is beginning to adapt this perspective. Christian theologians like Karl Rahner (1904–1984) and Karl Barth (1886–1968) at the beginning of the twentieth century already recognized this impulse, and such thought is more advanced in this ecumenical age. Death is not so readily understood as an "evil." It is, rather, a "problem" in Christianity because sin became attached to it. Sin constitutes alienation from God, and thus the experience of death most often is attended by fear, loneliness, and loss. Though biblical scholars still debate the meaning of the apostle Paul's assertions that the wages of sin are death (Rom. 5:12) and that the travails of the creation are attributable to human sin, more and more exegetes are less willing to claim biblical warrant for the dominant Augustinian idea that physical death, along with physical suffering and corruptibility, are consequences of the Fall. Further, an ever more scientifically informed consciousness, one that ever more understands how consciousness itself has evolved from simple matter, is also less inclined to fix material processes, including natural physical death, in dualistic terms of good and evil. Concurrently, such consciousness may recognize that its own knowledge of finitude—and so, an intuited transcendence—is precisely the "problem" that is occasioned by fear of death.

Other religious perspectives are less ambivalent in asserting a spiritual origin to death, and will ascribe death more to God's direct agency than to natural processes. Islamic thought, like some Christian perspectives, links natural death more specifically to the will of God. The Qur'an teaches of death that God determines the span of a person's life: "He creates man and also causes him to die" (Qur'an, XLV:26). How this might cohere with Western religious notions of divine agency, design of creative processes, and so forth, are a ripe field for exploration as the science-theology dialogue begins more to engage Islamic scholars.

Eastern religious perspectives

Hindu tradition, with all its variety, is distinguished by the doctrine of the transmigration of the soul, that is, the passing at death of the soul from one body or being to another. Life and death are aspects of an eternal cycle, as over and against the linear understanding of time embedded in Western science and theology. This process of *samsara* refers to journeying or passing through a series of incarnational experiences. One's karma accompanies one through these stages, and can be roughly defined as the moral law of cause and effect. Some popular reflection attempts to correlate karmic doctrine with Newtonian physics. The thoughts and actions of the past determine the present state of being, and in turn present choices influence future states. This karmic process characterizes the ever-changing flow of everyday experience, as well as the successive rounds of deaths and rebirths. Each moment conditions the next, and karma impacts the reincarnational flow of being.

An interesting new trajectory might yet be explored with respect to the linking of the spirituality of Hindu self-abnegation and new science. According to Hinduism, underlying the apparent separateness of individual beings is a unitary reality. Just as the ocean is composed of innumerable drops of water, so undifferentiated being manifests itself in human experience as apparently separate selves. The goal of life—lives—is, in the end, to realize the eternal self, or Atman, which by nature defies description. This assuredly difficult task (of the realization of something beyond description) aspires to deliverance from a potentially endless cycle of birth, death, and rebirth. To achieve deliverance, one must act with pure insouciance and detachment, with no attentiveness to cause or effect or reward; "one must act without desire or purpose, independently of the results of the action (Kramer, p. 33)." Thereby the detached self dies to self and into Krishna, becoming a "True Self." The goal of Hindu religion, in other words, is to transcend or leave karma and its cause and effect activity behind, which is perhaps not unlike new science's movement away from Newtonian physics.

The general understanding of death in Buddhism in all its varieties (Zen, Tantric, etc.) is not greatly different from Hindu thought. Generally (there are notable variations in Buddhist thinking) Buddhism understands death as a transition toward either phenomenal rebirth or release from the phenomenal realm into pure *nibbana* (nirvana). Practicing a life that would ensure the latter, or at least ensure a return to a desirable station after rebirth, requires total moderation of self-will and desire. Death itself involves grieved losses; thus, a certain kind of pastoral care obtains at Buddhist funerals. Even so, death is a phenomenon to be transcended, and so a reality that is not as real or as significant as the transcendent. A Buddhist, in other words, might well question the relevance of an entry about death. Likewise with other Asian religions. Confucianism, the philosophy of Lao Tze, and Daoism, for example, significantly moderate the Buddhist perspective of death, and locate the meaning of life more in practiced simplicity and propitious behavior than in preparing for a hereafter. There are ritually correct ways to conduct life and death, and so human consciousness is at its best simply when it is attentive to the fullness of the present.

Death and ultimate destiny

Finally, the question of whether death is an *end* is, to be sure, energetically discussed. This, of course, is where religious faiths diverge from final entropy as the last word. Christians believe in a resurrection of the dead—though not necessarily in physicalist terms—which is subject to a coming judgment by God and the possibility of eternal joy (heaven) or despair (hell). Within Judaism, only the most mystical and apocalyptic fundamentalists share any similar concept. In the main, Judaism understands the legacy of a person's life as the moral example left to the next generations. Biophysically there is nothing more. Islamic thought, on another hand, is more detailed with respect to an afterlife and the Qur'an vividly describes the spiritual cum physical states of bliss or torment that await after death. Some of the above, though certainly not all, could cohere with contemporary scientific perspectives. Natural science understands death as the final expenditure of energy, as dissipation into stasis. Yet, that which has decomposed may well be fodder for the recycling of life. Stars turn to dust, stardust has come to mind in human being, human being may become again stuff for stars, and untold other phenomena. Nevertheless, death as a modus unto new, organized, and sentient life is not a theme that natural science readily explores or articulates.

See also ESCHATOLOGY; FALL; ETERNITY; KARMA; LIFE AFTER DEATH; TRANSMIGRATION

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DUANE H. LARSON

DEEP ECOLOGY

The term *deep ecology* was coined by Norwegian philosopher Arne Naess (b. 1912) in 1973 to contrast two different approaches to environmental concerns. Whereas *shallow ecology* merely seeks to avoid excessive pollution and resource depletion, deep ecology advocates the need for fundamental shifts in perception, values, and lifestyles. Its basic premises are the intrinsic value of nature, the critique of industrial materialism and technology, and the application of ecological principles to human moral evaluations and actions. The word *deep* refers to the level at which human purposes and values are questioned. The goal of deep ecology is to clarify value priorities when establishing policies and practices.

Naess, influenced by Dutch philosopher Baruch de Spinoza and Indian political and spiritual leader Mohandas Gandhi, advocates a philosophy of ecological harmony and equilibrium (*ecosophy*) through four levels of questioning: (1) ultimate premises based on a person's worldview, for example, a particular religion or philosophy; (2) eight "Platform Principles" as common core principles independent of worldview; (3) general consequences derived from the platform; and (4) concrete decisions chosen by individuals and groups. Deep ecology challenges religions to respond to the concerns of environmental philosophy and so encourages the interconnection between religious and philosophical worldviews, scientific and empathetic studies of nature, and public policy and ethics. Deep ecology has been criticized for insufficient attention to gender issues, biocentric egalitarianism, and not adequately addressing economical and political injustices.

See also Ecofeminism; Ecology; Ecology, Ethics of; Ecology, Religious and Philosophical Aspects; Ecology, Science of; Gaia Hypothesis

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DEISM

Deism is the belief in a creator God who does not have any subsequent influence upon the world. Deism became influential in the West beginning in the seventeenth century, when it was seen that modern physics is compatible with an initial act of supernatural creation but appears to leave no room for subsequent interventions by God into the natural order. Although deism stands in marked contrast to traditional Jewish, Christian, and Muslim accounts of God's providential activity in the world, it is often advanced as an answer to the problem of evil: If God is unable to act in the world, God cannot be responsible for the suffering that arises within it.

See also Clockwork Universe; Evil and Suffering; God; Monotheism; Natural Theology; Panentheism; Pantheism; Theism

PHILIP CLAYTON

DESCARTES, RENÉ

René Descartes's philosophical importance for the advent of the modern scientific age is matched only by the difficulty of fully evaluating what his doctrines imply for religion. Born in Poitou, France, in 1596, Descartes lived most of his adult life in Holland, incurring the opposition, but also gaining the support, of Catholics and Protestants alike. He died in 1650 in Stockholm, where Queen Christina of Sweden had invited him to reside and instruct her in philosophy.

In his lifetime, he published works in both French and Latin, aimed at two slightly different audiences: *Discourse on the Method of Rightly Conducting Reason and Reaching the Truth in the Sciences* (French, 1637), *Meditations on First Philosophy* (Latin, 1641), *Principles of Philosophy* (Latin, 1644), and *Passions of the Soul* (French, 1649). Descartes also left unfinished works, notably *Rules for the Direction of the Mind* (Latin), *The Search for Truth* (Latin), *The Universe or Treatise on Light* (French), and *Treatise on Man* (French), as well as a voluminous correspondence in both French and Latin.

Method and faith

As a boy, Descartes attended the Jesuit College of La Flèche. Recalling his education in *Discourse on the Method,* Descartes denounces bookish learning and the vain pretense of scholastic philosophy, but favorably cites his love of poetry, his delight in mathematics, and his reverence for "our" theology. He emphasizes being firmly taught that revealed truths are above human intelligence. Stating moreover that the truths of faith have "always been first" in his beliefs, he explicitly says that these truths must be "set apart" from human opinions and must not be subjected to his method of universal doubt.

Descartes consistently maintains this position throughout his work, from the early and unpublished *Rules for the Direction of the Mind* to the mature *Principles of Philosophy,* where article seventy-six gives divine authority unambiguous precedence over human reason. Youthful diaries dating from his years of wandering and soldiering (1618–1620) reveal a feverish, unconventional, religious imagination, coupled with devout impulses.

A critical aspect of Descartes's mature philosophy for issues of science and religion is that his theory of mind (*res cogitans*) explicitly privileges free will over cognition. During an extended stay in Paris from 1620 to 1627, Descartes had frequent exchanges with leading religious figures: Marin Mersenne (1588–1648), who was also educated at La Flèche; Guillaume Gibieuf, a priest of the Oratory busy writing a book on freedom of the will; and Cardinal Pierre de Bérulle, who encouraged Descartes to pursue his reform of philosophy as a duty and vocation. In *Rules for the Direction of the Mind,* composed in the immediate wake of these meetings, Descartes affirms that revealed truths are held with even greater certainly than natural truths since "faith rests, not on an act of intelligence, but an act of will." He also distinguishes between cognition as such and the faculty of "affirming and denying" in an attempt to explain error, but the second faculty is not yet clearly identified with the free will, as it will be in the *Meditations* (1641) and in article thirty-two of the *Principles of Philosophy* (1644).

In 1628, Descartes moved to Holland in search of solitude. A letter to Mersenne dated April 15, 1630, reveals the extent to which physics and metaphysics were indivisibly combined in this search. Descartes explains that he would not have discovered the foundations of physics if he had not started with the rational discovery of self and God, which is indeed everyone's "first duty." God, Descartes maintains further, is "the first and most eternal" truth from which "all other truths proceed." Most dramatically, Descartes affirms that eternal truths are created: God has freely decreed that two and two make four, so that mathematical truths "depend on God's will no less than creatures." By 1630, while solving problems of mechanics and conducting dissections in his home, Descartes thus conceptualized divine freedom, the new physics, human self-knowledge, and dependence on God as intricately connected.

Cartesian naturalism

When Descartes learned of Galileo's condemnation in 1633, he cancelled plans to publish the cosmological *Universe or Treatise on Light* designed to unveil his new philosophy, citing at a later date "those whose authority has hardly less power over my action than my own reason over my thoughts." Instead, he published the *Discourse on the Method* anonymously in Leiden in 1637, along with "samples" of what his new method could achieve in geometry, optics and meteorology. Presenting his proof of self and God as pivotal to his own intellectual awakening, Descartes launches a framework in which physical phenomena, including biological phenomena, can be investigated experimentally according to materialist principles, while special mental events exhibiting voluntary features and characteristic of human beings are set apart and assigned to a distinct immaterial principle. In the *Discourse,* Descartes proceeds naturalistically in so far as he cites the empirical evidence of languages to conclude that the human "rational soul" is "in no way drawn from the potentiality of matter" and is therefore "not liable" to die with the body.

Cogito and freedom

Objections from all sides greeted Descartes's radical move to explain biological phenomena by means of inert microcorpuscular processes, as well as Descartes's bold noetic proof of self ("I think, therefore I am") and God. In 1639, desirous to clarify his views and to answer his critics, Descartes began writing his masterpiece, *Meditations on First Philosophy,* published in Paris in 1641. Composed in Latin, the text of the *Meditations* is followed by objections and answers, and is dedicated to Paris theologians. This time, the reader is led through a six-day journey of introspection and analysis designed to purge the mind of naïve empiricism, secure new grounds of noetic truth by rooting the human soul in God, and promote scientific investigation of the material universe (*res extensa*) as a way to cultivate personal happiness while working for the common good. From the demonic ordeal of the first day to the orderly reintegration of soul and body on the last, Descartes's core concern is to champion the inalienable gift of freedom that marks human beings as created in God's image. God, Descartes explains, has "left it in my power not to err" since he is always free to suspend judgment when evidence is insufficient. No evil demon, however powerful, can compel him to affirm as true what is merely doubtful. Human freedom thus manifests the will's inherent predilection for what is good and true, even in the absence of any known good or truth. Moreover, clarification in *Meditation* VI that the senses are meant for immediate survival and must therefore not usurp the function of reason in proposing to our freedom truths to be affirmed allows the same responsible exercise of judgment afforded by geometry to extend to the physical and experimental sciences.

The moral value of the scientific project thus lies primarily in the special opportunity it provides for deliberately searching out and affirming the truths that God has freely decreed. Significantly, in the *Principles of Philosophy,* charmingly dedicated to his favorite pupil Elizabeth of Bohemia, the principle of human freedom (article six) precedes the principle of cognitive certainty or *cogito* (article seven): The freedom to abstain from error is even more fundamental than the first cognitive certainty *I think; I am.* And as article thirty-seven goes on to explain, a human being's principle perfection lies in having a free will, and people act worthily whenever they deliberately choose what is true.

Further development of Descartes's views relating to proper use of the free will, truth, and human happiness, is found in Descartes's numerous letters to Elizabeth, and in the treatise on *The Passions of the Soul,* published in 1649. Descartes distinguishes between autonomous acts of will that terminate in bodily actions and those that terminate "in the soul itself, as for example, when we resolve to love God, or more generally, apply our thought to some immaterial object." Acts of the will that are based on false opinions leave one vulnerable to regret and remorse, while those that are securely based on knowledge of the truth lead instead to happiness and inner serenity. Descartes's letter to Queen Christina dated November 20, 1647, may serve to summarize Descartes's integration of religion and science since he declares that the highest good, for each and every human being, consists in "a firm will to do what is good and in the serenity to which this leads."

Influence

Although what is crudely described as *Cartesian dualism* has been mostly rejected by later philosophy, the problem of human freedom raised by Descartes and explained by him on the basis of a distinct, substantial, and immaterial spiritual principle (*res cogitans*), has be no means disappeared. The linguist Noam Chomsky has repeatedly drawn attention to some of the advantages of Cartesian rationalism for the defense of universal human dignity. In France, the philosopher Nicolas Grimaldi continues to emphasize the relevance of Cartesian freedom, while Jean-Luc Marion has in turn used Descartes as a springboard to elaborate new perspective on ethics. Most importantly, Cartesian scholars continue to discover seminal ideas in Descartes regarding the spiritual dimension of science. Daniel Garber, in particular, has shed light on the distinctive metaphysical features of Cartesian physics; Gary Hatfield has called attention to the deeply religious character of Descartes's notion of force; and Matthew Jones has initiated new questions on the spiritual dimension of Descartes's mathematics.

See also CARTESIANISM; FREEDOM; MODERNITY

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DESIGN

The apparent evidence of intelligent design in the universe has historically provided a kind of argument for the existence of God. The argument from design has evolved over time and in relation to changing scientific and philosophical perspectives. Interestingly, it has been formulated and reformulated in ways that show responsiveness to the discoveries and challenges it has encountered from science. This history of interaction reflects both the tensions and support at play between science and religion. Whatever tensions lie between science and religion, however, are in many instances eclipsed by tensions within them. Scientists, for example, disagree with one another as to whether there is, in fact, evidence of intelligent design in the universe. Theologians, conversely, differ as to whether and to what extent such evidence should have bearing upon the question of the existence of God.

The argument from design (the teleological argument) should first be distinguished from its close relative, the cosmological argument. In the cosmological argument, existence of the cosmos as a whole, because it is contingent and is not self-explanatory, serves as a kind of argument for the existence of God. God becomes the answer to the question "Why is there something and not nothing?" The cosmological argument for the existence of God is put forward on the ground *that* something exists, whereas the argument from design works from *what* exists. The world evidences order, adaptation, directionality—design, therefore an intelligent designer must have brought it into being.

This argument gets the name *teleological* from the Greek word *telos,* which means "end" or "goal." Teleological order entails the notion that processes or structures are fitted to bring about certain results, and in that sense are "designed." The concept of teleological ordering is not simple causal ordering. To say that the wind is fitted to circulate dust in the air is an example of causal ordering, but to say the eye is fitted for sight is an example of teleological ordering, pertaining to the adjustment of means to ends.

Greek philosophy and the early church

Accounting the history of the argument from design presents something of a challenge because the argument has followed a long and winding road with many interesting turns and occasional dead ends along the way. Historian Norma Emerton gives a fuller accounting of this history in "The Argument from Design in Early Modern Theology" (1989), but this brief treatment can only present an aerial survey of the landscape the argument has traversed. Forms of the argument in Western classical tradition go back at least as far as the early Greeks. The pre-Christian Stoics believed that the order and harmony of the cosmos demanded explanation. In 45 B.C.E. the Roman lawyer Cicero in his book *The Nature of the Gods* presented both pro and con arguments. Speaking for the Stoics, who favored a teleological view, Cicero posed the question, "When we see a mechanism such as a planetary model or a clock, do we doubt that it is the work of a conscious intelligence? So how can we doubt that the world is the work of the divine intelligence?" Cicero also presented the contrary view of the Atomists (Epicureans) that "The world is made by a natural process, without any need of a creator. . . . Atoms come together and are held by mutual attraction" (2.97). No intelligent designer need be postulated. If there were an intelligent designer, the atomist Lucretius argued, the world in some respects is really badly designed.

The early Christian church eagerly took up the idea of nature as a witness to God. In *Against Marcion* (1.18) Tertullian even spoke in terms of a double revelation in "God's two books": the book of nature (God's work) and the Bible (God's Word). Nature's design, as seen in the order and beauty of the heavens, the anatomy and physiology of living creatures, and the suitability of the environment to support life, became and has continued to be for Christian theology a pointer to God.

The Middle Ages: classic formulation

After the fall of the Roman Empire in the fifth century C.E., interest in the natural world dwindled and with it the pursuit of both science and natural theology. It was not until the thirteenth century that long lost classical philosophy and science were rediscovered. With this turn the argument from design reemerged and received its classic formulation.

Aristotelian physics with its emphasis on causality became widely influential. Purely physical processes were frequently explained in terms of "ends." For Aristotle there were four distinguishable types of cause: *final cause* (the maker of an object), *formal cause* (the design or blueprint according to which it is made), *material cause* (the raw material from which it is made) and *efficient cause* (the effort applied in actually making the object). At this time, the debate turned upon whether there is a formal cause (a design) and, having established that, proceeded to make theological claims of a final cause (a designer); if there is a design there must be a designer.

Christian theologian Thomas Aquinas was conversant with the science and philosophy of his day, and Aristotelian physics shaped his theology. The assumptions that an effect cannot be greater than its cause and that something can be *known* of the cause by observing the effect became building blocks of his particular formulation of the argument from design. Aquinas's arguments for the existence of God work *a posteriori* from observed facts of existence (effects) to what must be the case in the way of a *cause* to bring about such an effect. The most famous of his arguments are the "five ways."

Aquinas's "fifth way"(*Summa Theologica,* Part I, Question 2, Article 3) is perhaps the closest to the present concern. It starts from the orderly character of mundane events. Things meet their goals, even things that lack consciousness. Yet nothing that lacks awareness can tend toward a goal without direction from something that has awareness. As an arrow requires an archer to reach its goal, so also universal order points to the existence of an intelligent *orderer* of all things. For Thomas all causes acting in the physical universe are instrumental and have to be "used," as it were, by a primary agent. To assume that all this causation is self-explanatory is like expecting that a bed will be constructed if only one puts the tools and materials together "without a carpenter to use them." Aquinas then images God on the model of an artisan (in the mode of final cause).

Also relevant is the first of the "five ways." In thirteenth-century physics and astronomy, the four basic elements were thought to be under the dynamic influence of the stars, and lower celestial bodies were considered to be moved about by those at greater distance from the Earth. Everything that moved did so because it was moved by something else. God was the *Unmoved Mover* behind all the motion.

The section in the *Summa Theologica* where the "five ways" are presented is a response to the question, "Is there a God?" It begins with the objections that there must not be a God because there is evil in the world and because natural effects can be explained by natural causes. Interesting, these same objections still play an important part in contemporary discussions.

The scientific revolution: challenges and new forms

When Isaac Newton began working out the physical laws of nature during the late seventeenth century, he demolished one form of Aquinas's argument from design when he explained the motion of bodies according to fundamental mechanical physical laws. There was no longer need to appeal to direct divine intervention to move things around in space. However, in another sense, Newton only reformulated the argument, for he assumed God was the architect of the physical laws he had discovered. Science could explain matter and motion without recourse to supernatural forces, but these mechanical secondary forces were simply the working out of structural conditions given by God at the creation.

As many new discoveries were made during the scientific revolution, there came to be greater ambivalence about the place of natural theology. Some theologians were concerned that natural theology might usurp revelation. Conversely, some scientists were concerned that appeal to final causes might usurp attention to physical causes. Science needed to preserve its integrity and avoid becoming a "quarry" that was mined for theological arguments. Nevertheless most theologians, philosophers, and scientists (people like Francis Bacon, Robert Boyle, René Descartes, and Newton) assumed the legitimacy of natural theology.

Eighteenth and nineteenth centuries: new form and challenges

In the eighteenth century philosopher William Paley in *Natural Theology: Or, Evidences of the Existence and Attributes of the Deity, Collected from the Appearances of Nature* (1802) reformulated the argument from design by attending to specific instances of design. He took the eye as a case in point and the ways in which the parts of the eye cooperate to produce sight. To explain this adaptation of means to ends, he claimed, one needs to postulate an intelligent designer, much as one would if one found a watch while crossing a heath; rather than assume the watch had come together by chance, one would assume an intelligent designer put it together.

David Hume in *Dialogues Concerning Natural Religion* (1779) attacked Paley's position for privileging the model of human design of artifacts. This approach, he claimed, skews the argument. Why not use another model, for instance the model of biological generation, which does not require intentional design? One could as easily say the universe is like an organism, therefore there must be a cosmic womb.

Paley had his defenders, those who preferred his analogy to Hume's. They observed that in biological generation creatures reproduce themselves rather than producing new and various things. When one asks why a rabbit has organs that are so well adapted to meet its needs, one is not helped by the answer that this is because it springs from other rabbits that were similarly adapted. Hume countered that if the best answer to such a problem is that there is an intelligent designer, then one still has to give an account for why the designer has a mind that is so well-fitted for designing. If the design comes from the designer, where does the designer come from? With either option, one ends up with an infinite regress.

Immanuel Kant in his *Critique of Practical Reason* (1788) also put forward objections to the argument from design. He thought that science and religion should be completely separate, and natural theology was for him a contradiction in terms. Nevertheless, he said in the conclusion to the *Critique,* "Two things fill my mind with wonder and awe . . . the starry sky above and the moral law within" (p. 166). Still, it was the latter—the moral law within—and not the former that he took to be the clearer pointer to God and God's goodness.

With the publication of Charles Darwin's *Origin of the Species* in 1859, the argument from design met a truly formidable challenge to its credibility. In the theory of evolution there came to the fore a genuine alternative explanation for apparent design in organisms. One was not left with mere chance on the one hand, or intelligent design on the other. Organic structures come to be what they are by development from simpler forms through purely natural processes of mutation and natural selection over an extended period of time. No intelligent designer is needed to design the eye for sight.

Twentieth century: new forms and new challenges

One might think that Darwin had dealt arguments from design the decisive blow, but the argument arose with new vitality in the twentieth century. The shape was, however, no longer examination of the particular instances of design but the general principles behind apparent design. In a manner parallel to what happened with Newton's discovery of physical laws, with Darwin's discovery of principles of natural selection the theological interest shifted from particular divine interventions to the wider divine design. What makes mutation and natural selection work in the way that it does? How did material existence come to be self-organizing in the way that it is?

This approach began taking shape in the 1920s with the work of Frederick R. Tennant in *Philosophical Theology* (1928–1930). He presents a fresh discussion of the teleological argument pointing to six kinds of adaptation that seem to evidence design and, when taken together, to point toward a theistic interpretation:

(1) The intelligibility of the world.

(2) The adaptation of living organisms to their environment.

(3) The ways in which inorganic life is conducive to the emergence and maintenance of life.

(4) The way in which the natural environment nurtures moral development in human beings through coping with hardships.

(5) The overall progressiveness of the evolutionary process.

(6) The aesthetic value of nature.

Here, in rudimentary form, are the elements of what became the argument from design in the contemporary discussion—the intelligibility of the universe and its suitability for life. Interestingly, these newly emerging forms of the argument arise from science, while some of the direct challenges to grounding intelligent design thinking in observations of the natural world come from of theology.

Theologian Karl Barth, for example, exemplifies a twentieth-century theological disillusionment with natural theology—the idea that there is a point of contact whereby one may easily perceive who God is by studying the natural world. Barth's context, Germany during the rise of the Third Reich, shaped his theological critique. The risk of natural theology is that what one discovers will not be God, but one's own reflection, which one then names as God. It is too easy to find God in one's race, culture, and interests. Barth observed the failure of Protestant liberalism to issue a prophetic challenge. He insisted on the prophetic distance of revelation over against the "culture Christianity" of his day. So the early Barth said no (*Nein!*) to natural theology and cautioned that God is "wholly other."

A second theological challenge to intelligent design thinking arose in twentieth-century experience with the problem of evil. This is not a new challenge, but one to which any form of the argument from design (in any age) has to give a thoughtful response. But during the twentieth century, the challenge of the problem of evil was sharpened in new ways. The optimism of the Enlightenment and the nineteenth century was severely chastened. With two world wars, the Holocaust, and ethnic cleansing, evil has proven too pervasive and too heinous to be dismissed as a brief passage on the way to God's good ends, the necessary dark shades in God's beautiful painting.

Theological responses to this challenge have been mixed. In response to the problem of evil, for example, some maintain design, by which they mean a kind of divine blueprint is working itself out inexorably and in all its detail. If one could but see world processes from God's perspective, all evil would be only *apparently* evil, a matter of one's limited perspective or a necessary means to some greater good. Other theologians, especially process theologians, are willing to rethink the meaning of design in the face of evil. If absolutely everything that happens comes about by God's design, then what does one make of all the blind alleys, waste, suffering, and evil that have attended this process so carefully designed and closely controlled by God?

Design in the early twenty-first century

In the early twenty-first century, the discussion of design is being engaged with renewed vigor. Discussion centers on the somewhat negative evaluations emerging from chaos theory and evolutionary biology, and around more positive evaluations based upon the intelligibility of the universe and the suitability of the universe for the emergence of life. In these discussions, there are differences of viewpoint within the fields of theology and science that are every bit as great as some of the differences between these fields. It is not uniformly the case that theology affirms design while science denies it; the discussions are much more nuanced than that.

The reintroduction of the role of chance and contingency in the way the world works has, for many, challenged notions of design. Ian Stewart in *Does God Play Dice? The Mathematics of Chaos* (1989) has noted that with the advent of quantum mechanics the clockwork universe of Newton's day has become a cosmic lottery. "The very distinction . . . between the randomness of chance and the determinism of law, is called into question. Perhaps God can play dice, and create a universe of complete law and order, in the same breath." As one learns more about chaos theory, the question becomes "not so much *whether* God plays dice but *how* God plays dice" (p. 1–2).

Biologist Jacques Monod in *Chance and Necessity* (1972) expressed the conclusion of some: "The ancient convenant is in pieces: Man at last knows that he is alone in the unfeeling immensity of the universe, out of which he has emerged only by chance. Neither his destiny nor his duty have been written down" (p. 167).

Theologians who wish to uphold design are responding variously to chaos theory and the observations of science that much of what occurs in the universe is random activity, pure chance. A great deal depends upon their differing understandings of what one must mean by God's "design" as presented above. Those who mean "a detailed preexisting blueprint in the mind of God" hold a view that is antithetical to chance. These theologians tend to argue that what appears to be random is only apparently so. They point out that even Albert Einstein held the position that what appears to be a random occurrence would prove not to be random if only the causal activity behind it could be seen.

Other theologians do not understand design in such a constraining mode. They would allow that it might be part of the "design" that some things happen by necessity, others by chance, and others in open interplay of relative freedom. The design might include contingency as well as regularity, chaos as well as order, novelty as well as continuity. Design might simply mean setting the systemic conditions that make life and consciousness possible, and then allowing it all to unfold. This view has the capacity to incorporate elements of chance as well as necessity into "design." This shift has profound implications for the way in which God and God's relation to the world are viewed. As John Polkinghorne expressed it, this view is "consistent with the will of a patient and subtle Creator, content to achieve his purposes through the unfolding of process and accepting thereby a measure of the vulnerability and precariousness which always characterize the gift of freedom by love" (1987, p. 69).

Process theology takes this general approach but allows for a more interactive role for God. God's purposes are expressed not only in setting the unchanging structural conditions and then letting things be, but also in the novel possibilities introduced. Divine creativity works within order and chaos, persuading toward good ends. It works with and does not coerce the self-creating activity of creatures.

Evolutionary biology, generally speaking, excludes appeal to the notion of intelligent design in organisms. The explanation of life in all its diversity, according to neo-Darwinist Francisco Ayala, lies in the blind, unguided, and mechanical process of natural selection. There are teleological processes internal to organisms; the heart, for example, has the purpose of pumping blood. However, these are not to be accounted for by divine design but through the process of natural selection and the development over time of features that prove reproductively successful. This process needs no external teleology directing it from outside. If there is anything like a "goal" or "end" to which things tend, it is reproductive efficiency.

To these assumptions, most contemporary theologians (except for creationists who reject evolutionary theory altogether) would accede. The question may still be posed as to why all things are oriented toward reproductive success. Can one infer, for example, that ultimate reality is in some sense fecund and biophilic? Why does natural selection work in the way that it does? How did material existence come to be self-organizing in the way that it is? Moreover, the mode of operation of evolution is a source of wonder that seems to point beyond itself. Differentiation, self-organization, and interrelation seem to characterize the evolutionary process. As Paul Davies points out, life forms have emerged from primeval chaos in a sequence of self-organizing processes that have progressively enriched and complexified the evolving universe in a more or less unidirectional manner. All this diversity, as John Haught has noted, comes from the informational sequencing of only four DNA acid bases. It is a remarkable state of affairs.

Nature seems to operate with a kind of "optimization principle" whereby the universe evolves to create maximum richness and diversity. Davies observes "that this rich and complex variety emerges from the featureless inferno of the Big Bang, and does so as a consequence of laws of stunning simplicity and generality, indicates some sort of matching of means to ends that has a distinct teleological flavor to it" (1994, p. 46).

As Paul Davies observed, "Human beings have always been struck by the complex harmony and intricate organization of the physical world. The movement of the heavenly bodies across the sky, the rhythms of the seasons, the pattern of a snowflake, at the myriads of living creatures so well adapted to their environment—all these things seem too well arranged to be a mindless accident. It was only natural that our ancestors attributed the elaborate order of the universe to the purposeful workings of a deity" (1994, p. 44). However, with the increased understanding that science has brought, one no longer needs explicit theological explanations for these phenomena. The questions that remain concern why the universe is lawful, coherent, and unified in this way. Why is it intelligible? Scientists themselves normally take for granted that people live in a rational, ordered cosmos subject to precise laws that can be uncovered by human reasoning. Yet why this is so remains a "tantalizing mystery" (Davies 1992, p. 20). Ian Barbour quotes Einstein as saying, "the only thing that is incomprehensible about the world is that it is comprehensible" (1990, p. 141).

Not all scientists agree here, however. Theoretical physicist Steven Weinberg at the end of his book, *The First Three Minutes* (1977), makes the statement, "the more the universe seems comprehensible, the more it also seems pointless" (p. 149). Analysis of cosmos does not, for him, yield clear and evident purpose. Advocates of the anthropic principle, John Barrow and Frank Tipler (also theoretical physicists), make a different interpretation. The very laws that Weinberg takes to be indifferent to human beings seem to them to suggest the presence of an intelligence that "wanted" human beings to evolve.

Biological systems do have some very particular requirements and these requirements are in fact met by nature. There are cosmic coincidences of striking proportions. For example, if the expansion rate of the universe after the Big Bang were greater by an infinitesimally small proportion, stars and planets would not have formed. If it were any smaller, the universe would have collapsed upon itself. Similarly, the inverse square laws that apply to gravitational, electric, and magnetic forces are essential to the stability of the atoms and solar systems. Even a small change in the force-distance relation would jeopardize life as we know it. There are countless other instances of what Barbour has called "remarkable coincidences" (p. 136)

The odds against this special set of physical conditions and natural laws that make our lives possible are astronomical. The theoretical physicist Stephen Hawking has said, "The odds against a universe like ours emerging out of something like the Big Bang are enormous. I think there are clearly religious implications" (p. 121).

Detractors will say that one could only observe a universe that is consistent with one's existence (the weak form of the anthropic principle). Moreover, there is a possibility that there are an infinite number of universes. It is also possible that other, vastly different, forms of life have emerged elsewhere under different initial conditions and physical laws, although, as of 2002, none are known and this remains an open question.

If it is the case that the existence of life requires finely tuned conditions and these do in fact exist, then the suggestion of intelligent design does not seem an extravagant metaphysical claim. It is not more extravagant than the claim for infinite random universes. Some would apply the criterion of Ockham's Razor and argue that the hypothesis that there exists an intelligent designer serves as a simpler and therefore better explanation (applying Ockham's Razor criterion).

Theological responses to the argument from design emerging from some scientific accounts of the intelligibility of the universe and its suitability for life are mixed. From this scientific picture of the universe, many theologians are willing to make the interpretive leap to the existence of an intelligent designer—a creator with an investment in life, and even, apparently, intelligent life. If one does see design, it is hard not to make the leap to thoughts of an intelligent designer. While one may imagine a designer without a design, a design without a designer would be a surprising thing indeed.

Nevertheless, many theologians do not want to invest too much import in the argument from design. This is, in part, because the evidence is ambiguous. Scientists do not all agree, for example, that evolution manifests the directionality that is often appealed to as evidence of design. Paleontologist Stephen Jay Gould holds that while early evolution might be said to *complexify* (there was no other direction to go), as things steadied out life randomly got simpler as often as it got more complex. Complex life forms are actually disadvantageous; they are easy prey to mass extinctions that periodically plague the planet.

Even if the weight of scientific opinion were clearly in the side of design in the universe, the leap to an intelligent designer is still a large interpretive leap, and not one that all impartial observers would make. And even if this be granted as a reasonable inference from the evidence, a "designer" is not yet "God" in the sense of the creator of all things visible and invisible, infinite in goodness, wisdom, and power.

Theologically speaking, the argument from design is somewhat limited in its efficacy. At best, it is a pointer toward God; it cannot offer a convincing proof for God's existence. For the believer, evidence of design in the universe seems a kind of confirmation that there is reason to believe that it is not *unreasonable* to believe. Whether one believes or does not believe is a question of interpretation, as some would have it, "a leap of faith." One that is inevitably "underdetermined by the data."

The current state of the discussion between theologians and scientists is one of active engagement and mutual illumination. There are exciting new directions and many diverse perspectives represented. Old assumptions that theologians will uniformly support arguments from design while scientists will uniformly oppose them, simply do not hold. Scientists, for example, disagree with one another as to whether there is in fact evidence of intelligent design in the universe. Theologians, conversely, differ as to whether and to what extent such evidence would have bearing upon the question of the existence of God. The questions remain open and interesting.

See also ANTHROPIC PRINCIPLE; ARISTOTLE; CHAOS THEORY; CONTINGENCY; COSMOLOGICAL ARGUMENT; CREATION; CREATIONISM; CREATION SCIENCE; DESCARTES, RENÉ; DESIGN ARGUMENT; DIVINE ACTION; EINSTEIN, ALBERT; EMERGENCE; EVIL AND SUFFERING; EVOLUTION; EVOLUTION, BIOLOGICAL; GOD; INTELLIGENT DESIGN; MUTATION; NATURAL THEOLOGY; NEWTON, ISAAC; PROCESS THOUGHT; REVELATION; SUPERNATURALISM; TELEOLOGICAL ARGUMENT; THOMAS AQUINAS; TWO BOOKS

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ANNA CASE-WINTERS

DESIGN ARGUMENT

The argument from design argues from the order, adaptation, and directionality evident in the cosmos that an intelligent designer (whom theologians call God) must have brought it into being. In religion and science discussions this argument has held a prominent place historically and is continually reformulated in response to discoveries and challenges from science. There is an ongoing discussion among scientists as to whether the cosmos in fact manifests sufficient order, adaptation, and directionality to indicate design. Discussion continues among theologians as well concerning the effectiveness and limitations of an argument from design for establishing the existence of God.

See also CREATION; CREATIONISM; CREATION SCIENCE; DESIGN; INTELLIGENT DESIGN; TELEOLOGICAL ARGUMENT

ANNA CASE-WINTERS

DETERMINISM

The concept of determinism conveys the idea that everything that happens could not have happened in a different way than it actually did. Or alternatively, everything that happens, happens by necessity. However, as simple as this may sound, the concept of determinism is one of the most difficult and controversial concepts in Western philosophy.

Philosophers often distinguish different kinds of determinism. First, there is *scientific determinism,* which was inspired by classical physics. One interpretation entails that everything in the universe is governed by universal laws. *Universal* in this context means that the laws are the same everywhere in the universe and at all times, and that they apply to all events and objects. A second interpretation of scientific determinism holds that every event has a sufficient cause. These two interpretations of scientific determinism combined can yield an argument for *Laplacian determinism*: If every event has a sufficient cause, and if every event is governed by universal laws, then one could in principle predict exactly the subsequent evolution of the universe if one had knowledge of all the initial conditions of all objects in the universe combined with knowledge of all the laws of nature.

Note first that this interpretation denies the existence of chance or probabilistic laws. Since the second half of the twentieth century, however, more and more scientists argue that not all natural laws are deterministic, but that some of these laws may be inherently statistical in nature. This line of argument could constitute an argument for indeterminism, and is explored further by Karl Popper (1902–1994). Note furthermore that, though Laplacian determinism is an ontological view, it is mostly formulated in epistemic terms, relating to knowledge and predictive capabilities. Hence, as John Earman argues, one must keep in mind that scientific determinism is first of all a claim about how the world is constituted. As such one must distinguish this ontological claim from the epistemological claim to predictability, even though both often go together. That determinism does not always entail predictability is testified by chaotic systems, which display deterministic though unpredictable behavior.

If scientific determinism is taken seriously, it can result in a worldview that affirms the concept of *metaphysical determinism.* Metaphysical determinism conveys the idea that if everything in the universe is governed by universal laws, and if every event has a sufficient cause, then there is only one history possible. One can clarify this idea by using possible-world semantics. If a possible world starts off with exactly the same initial conditions as the actual world and with exactly the same universal laws, its evolution would look the same in every detail. As such, metaphysical determinism entails scientific determinism, but not necessarily vice versa, even though scientific determinism could be used to defend metaphysical determinism.

Both metaphysical and scientific determinism are threatened by the indeterminism of quantum mechanics, when interpreted as an ontological feature of the world. If at the quantum level there is genuine indeterminism, then, it might be argued, not everything has a sufficient cause, so that the histories of two possible worlds with exactly the same initial conditions, but with quantum indeterminism, might develop in completely different ways. However, scientists like David Bohm (1917–1992) have tried to restore determinism at the quantum level by invoking hidden variables, though this proposal is not uncontroversial. Furthermore, it must be kept in mind that quantum theory might not be the final theory, but might in the future be replaced by an alternative theory that forces its philosophical interpretation to affirm either determinism or indeterminism.

A third kind of determinism, closely related to scientific determinism, is *mathematical determinism.* Mathematical determinism is the "logical" complement of scientific determinism, and has become increasingly important in chaos theory. In mathematical determinism the initial conditions are numerical inputs, and a mathematical function takes the place of the universal law. Mathematical determinism now entails that, given an arbitrary value of the initial conditions, calculating the mathematical function will yield one and only one outcome. In other words, given an arbitrary value of the initial conditions and a mathematical function, there is only one outcome possible. In the case of mathematical chaotic systems, problems arise with specifying the initial value. Because knowledge of the initial conditions is limited, the outcome of a chaotic evolution cannot be predicted, yet as a mathematical system it is deterministic, which means that the outcome of the calculation, given the initial conditions, could not be other than it actually is.

A fourth kind of determinism is *logical determinism.* Logical determinism is about propositions, and entails that any proposition about the past, present, or future of the world is either true or false. As such, logical determinism is grounded in Aristotle's law of the excluded middle, which holds that a proposition cannot be both true and false at the same time. Developments in so-called "fuzzy logic" have challenged this kind of determinism.

Theological determinism constitutes a fifth kind of determinism. There are two types of theological determinism, both compatible with scientific and metaphysical determinism. In the first, God determines everything that happens, either in one all-determining single act at the initial creation of the universe or through continuous divine interactions with the world. Either way, the consequence is that everything that happens becomes God's action, and determinism is closely linked to divine action and God's omnipotence. According to the second type of theological determinism, God has perfect knowledge of everything in the universe because God is omniscient. And, as some say, because God is outside of time, God has the capacity of knowing past, present, and future in one instance. This means that God knows what will happen in the future. And because God's omniscience is perfect, what God knows about the future will inevitably happen, which means, consequently, that the future is already fixed.

All forms of determinism (except perhaps mathematical determinism) challenge the idea of free will. Or rather, they render the experience of free will an illusion. Theological determinism moreover raises big problems for the idea that God is perfectly good. For, if everything is God's action, the evil and suffering that happens is also due to God's actions. Or, alternatively, if God already knows what evil will happen, why does God not prevent it from happening? Some theologians have argued for divine self-limitation (*kenosis*) of God's omniscience and omnipotence to warrant human freedom.

See also CAUSALITY, PRIMARY AND SECONDARY; CHANCE; CHAOS THEORY; CLOCKWORK UNIVERSE; CONTINGENCY; DIVINE ACTION; FREEDOM; HEISENBERG'S UNCERTAINTY PRINCIPLE; INDETERMINISM; KENOSIS; OMNIPOTENCE; OPEN UNIVERSE; PHYSICS, CLASSICAL; PHYSICS, QUANTUM

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TAEDE A. SMEDES

DEUS EX MACHINA

See GOD OF THE GAPS; SKYHOOKS

DHARMA

Dharma literally means "what holds together" and thus is the basic Hindu concept for all order, whether individual, social, or cosmic, as established by the Veda. For moral or social behavior it is codified in the teachings of the Laws of Manu. For traditional views of scientific knowledge, arising from the Veda, it is knowledge of the cosmic order of the universe. According to Mimamsa philosophy, dharma is what is enjoined in the Veda. It is religious duty which, when performed, brings merit to the individual and fosters the inherent order of the universe. Its neglect brings personal demerit and cosmic chaos.

See also BUDDHISM; HINDUISM

HAROLD G. COWARD

DIALOGUE

See MODELS; SCIENCE AND RELIGION, METHODOLOGIES; SCIENCE AND RELIGION, MODELS AND RELATIONS

DIRECTIONALITY

See CONVERGENCE; TEILHARD DE CHARDIN, PIERRE

DISORDER

Disorder can be described as the absence of structure and differentiation. Its religious and scientific connotations have been negative in many cultures, identifying God as the source of creational order. In thermodynamics, the entropy of a closed system is a measure of its disorder, which can only increase in due course of time. Chaotic systems show disorder, insofar it is impossible to indefinitely predict the behavior of their elements. Still, an overall structural order can emerge from inherent disorder, which may indicate that systemic order is transcended disorder and that a certain amount of disorder is necessary for emergent and adaptive structural processes.

See also CHAOS THEORY; EMERGENCE; ENTROPY

DIRK EVERS

DISSIPATIVE STRUCTURES

Dissipative structures are nonequilibrium thermodynamic systems that generate order spontaneously by exchanging energy with their external environments. Dissipative structures include physical processes (e.g., whirlpools), chemical reactions (e.g., Bénard cell convection), and biological systems (e.g., cells). Chemist and physicist Ilya Prigogine (b. 1917), whose research on dissipative structures has been seminal, found that these structures, when far from equilibrium, can transform small-scale irregularities into large-scale patterns. The most intriguing application of Prigogine's ideas is to the origin of life and biology generally. It is an open question whether the complexity and specificity inherent in biological systems can be reduced to the thermodynamics of dissipative structures.

See also COMPLEXITY; ENTROPY

WILLIAM A. DEMBSKI

DISSONANCE

See MODELS; SCIENCE AND RELIGION, METHODOLOGIES; SCIENCE AND RELIGION, MODELS AND RELATIONS

DIVINE ACTION

One fundamental theme in the theistic religious traditions has been that God acts purposefully to call the world into being and to guide its history. Judaism, Christianity, and Islam all include in their sacred scriptures substantial (and overlapping) collections of stories about divine action. These stories present a drama of magnificent scope, setting human events in the wider context of cosmic history and portraying God's relationship with humans as an ongoing dialogue characterized by repeated divine initiatives, inconstant human responses, painful reversals, and renewed opportunities. The God of the biblical narratives establishes a covenant with Abraham, liberates the Hebrew people from slavery and gives them the law, makes Israel an independent kingdom, raises up prophets who call the nation to justice, and judges and sustains the people in their tragedies of political defeat and exile. Christians take up these stories and interpret them in terms of their conviction that God has acted in a stunning new way in Jesus of Nazareth, and Muslims later proclaim that the history of divine action receives its definitive articulation in the text of Qur'an given by Allah to the Prophet Mohammed. Each of these religions of the book places stories of divine action at the center of its understanding of God; God is known, in part, as the One Who Acts in these ways, and divergences in the stories told by these traditions contribute crucially to differences in their conceptions of the character and purposes of God. The canonical narratives, therefore, do not remain simply a record of past understandings of God's activity; rather they set the context within which communities of faith interpret their contemporary experience as part of an ongoing history of divine action in the world.

Modern challenges

In addition to playing this central role in the theistic traditions, the idea that God acts in the world raises a host of difficult questions. The transition from sacred stories to theological claims about divine action involves subtle interpretive judgments. The biblical texts, for example, do not speak with a single voice, but rather depict God in strikingly diverse ways; in order to construe them as contributing to a relatively unified narrative of God's acts, decisions must be made about which elements are central and which are peripheral, and these theological choices can generate a wide range of different readings. Further, modern techniques of critical scholarship have contributed greatly to understanding the literary forms, functions, and history of these texts. One effect of this scholarship has been to show how complicated it is to move from scriptural stories to conclusions about historical events. A theologian who appeals to biblical and liturgical talk about God's mighty acts in history must think through what this language means once it is granted that the stories are not straightforward reports of surprising things that happened long ago. If, for example, one acknowledges the legendary and symbolic character of significant aspects of the exodus story, and if one doubts that each of the miraculous divine interventions occurred just as it is related in the text, then what should one say about what God did to liberate the Hebrew people from slavery in Egypt? This is a question that Langdon Gilkey (1919–) pressed with great effectiveness against the biblical theology movement, represented by theologians like G. Ernest Wright (1909–1974) and Reginald H. Fuller (1915–), who insisted that God is known through mighty acts in history but who were unwilling to take at face value the biblical stories of those acts.

The natural sciences raise additional powerful questions for traditional claims about divine action. In a prescientific view of the world, one compelling way to make sense of events is to ascribe them to the action of person-like but super-human powers. With the rise of the sciences, these supernatural agencies and teleological (i.e., purposive) explanations tend to be displaced in favor of appeal to efficient causes that are themselves a part of nature. As the various sciences developed, the web of explanations they offer has expanded and become increasingly integrated in interlocking structures of natural law. At the same time, the sciences have progressively eliminated from their theories the remaining elements of explicit theological explanation that reflect the close historic association of science and religion. A paradigm here, perhaps, is the transition from Isaac Newton (1642–1727) to Pierre-Simon Laplace (1749–1827). Newton's calculations indicated that there would be accumulating errors in the orbits of the planets. This, he suggested, is corrected by God, who intervenes periodically to set the solar system aright. A hundred years later, Laplace demonstrated that these variations in orbital speed are part of a mathematically predictable cycle, and it is said that when he was asked about the role of God in his physics, he triumphantly replied that he had "no need of that hypothesis." The sciences, it appears, can get along perfectly well without appealing to God as a element in their account of the world. Theologians have had to grapple, therefore, with questions about the relation between the traditional affirmation that God acts in the world and scientific accounts of that world as an intelligible natural order. How do God's purposes engage a world whose history develops within a finely woven skein of natural law?

Creation as God's fundamental act

At the heart of virtually any theological account of divine action will be some understanding of God's fundamental activity as creator. Creation has been construed in various ways in the history of the theistic religions, but one particularly prominent view has understood creation as a free and intentional divine act that calls the world into being and continuously sustains its existence. There are four elements in this account. First, creation is a free divine act in the sense that it does not follow necessarily from the divine nature; God could exist without the world in undiminished fullness of being. God chooses to create not because God must have the creature, but because it is good for the creature to be. The act of creation, therefore, is an expression of generosity and love. Second, creation is an intentional action insofar as God brings the world into existence knowingly and purposefully. These first two claims distinguish classical accounts of creation from emanationist accounts, such as that of the neo-platonic philosopher Plotinus (205–270 C.E), according to which the perfection of being in God necessarily overflows into a progression of diminishing forms of existence. Third, perhaps the most striking feature of this theological view is that God's creative act accounts for the very being of the creature. There is no pre-existing unformed "stuff" that constrains and shapes God's creative choice. God creates from nothing (*ex nihilo*), that is, apart from God's creative act, nothing at all would exist other than God. Finally, the world that God creates has no power to continue to exist on its own. Finite things depend at every moment on a divine creative action that continuously sustains, or conserves, their existence. Creation, therefore, is not a one-time event completed at some moment long ago but rather is an ongoing active relationship of God to the whole finite world throughout its history. This stands in contrast to the view associated with eighteenth century deism, which responded to the rise of Newtonian mechanics by arguing that the creator establishes the structure of the world and then leaves it to exist and to operate on its own.

This way of thinking about God's action at the foundation of the world will pervasively shape one's interpretation of traditional talk about God's action within its history. On this account of creation, every event in the world depends upon the action of God; it will be true to say that God acts in all things. Theologians have not wanted to conclude from this, however, that God is the only effective cause or agent, or that created causes merely appear to bring about effects in the world while God alone directly produces all change. Views of this sort came to be called *occasionalism,* because they regard created causes merely as occasions for the action of God in bringing about the effect. In rejecting this view, Thomas Aquinas (c. 1225–1274) affirmed that God gives created things active and passive causal powers of their own, that is, the capacity to affect other things and to be affected by them. God is always the primary cause who directly sustains the existence of every creature, but God also chooses to act indirectly through the operation of created, or secondary, causes. This provides a further sense in which events in the world may be understood as God's acts, namely, that God acts by means of the order of nature to produce effects in the world. This mode of divine action is analogous to indirect human action in which various means are used to achieve one's ends. Aquinas notes that when the artisan uses a hammer and chisel to shape stone, the effect is produced both by the tools and by the human agent who wields them, though the two causes operate on different levels. Similarly, God acts by means of the entire network of causal relations that constitutes the created world. God's engagement with finite causes goes much deeper, of course, than the involvement of human agents with the tools they use. For God directly sustains the very existence of the finite cause (traditionally called *divine conservation*) and, on some accounts, empowers it to act as it does (traditionally called *divine concurrence*). Hence, by establishing the lawful structures of nature and setting the boundary conditions under which they operate, God indirectly produces the vast range of effects that together make up the history of the universe. Indeed, if the universe were a causally closed, deterministic system, then everything that happens would be an indirect act of God. On the other hand, if the universe includes moments of indeterministic openness within its structure (e.g., either as chance or as self-determining freedom), then God will set the direction of cosmic history but not necessarily specify all of its details.

The classical conception of creation that underlies this account of divine action is by no means the only view found in the theistic traditions. Process, or neo-classical, theologies reflect a contemporary alternative approach that has different implications for divine action in the world. These theologians make use in various ways of the thought of Alfred North Whitehead (1861–1947) and Charles Hartshorne (1897–2000). Within

Whitehead's metaphysical scheme, every entity, from the simplest elements of the physical world to God, is a creative synthesis of relations to others. God is not the absolute source of the world's existence, rather God and the world together constitute the basic structure of reality, which is a process of creative becoming. God plays a central role, however, in the world's unfolding history, for God makes a crucial contribution to the direction of each entity's development and God embraces that individual's achievement within the ongoing divine experience. On this view, God acts in every event to lure and persuade, and though God's power is limited, the reach of God's influence is not. Charles Hartshorne explores similar ideas about the inherently social nature and persuasive power of God, but develops them through the analogy of divine embodiment in the world. God and world form an organic unity of many distinct sub-centers of activity; God shares the experience of all the parts and acts through them with an immediacy analogous to (but even more profound than) that with which humans act through their bodies. Once again, God's powers of action are limited by the given structure of the divine life as a social organism and by the partial independence and self-creativity of the constituents that are united in this structure. One of the strengths of this approach, however, is that it provides a vivid expression of God's universal responsiveness and preeminent influence in shaping the destiny of the cosmos.

Particular divine action

The theistic traditions have affirmed not only that God shapes the overall direction of cosmic history through the act of creation, but also that God acts in particular events to advance the divine purposes for the world. The mighty acts of God related in the biblical stories provide paradigmatic examples of this form of divine action. Modern theologians have struggled to know what to say about particular divine action. There are at least three senses in which specific events might be singled out as acts of God in a special way. First, an event may be distinguished from others by virtue of its disclosive, or revelatory, importance. Particular events may become the occasion through which individuals and communities recognize with special clarity the presence and purposes of God. It need not be the case that God acts in these events in a way that is different from God's universal action in every event. What marks them out as special is not a distinctive mode of divine action within them but rather their power to reveal and exemplify the direction of God's work in history. If, for example, the escape of the Hebrew people across the shallows of the Red Sea involved only the ordinary processes of nature coupled with free human decisions, this event may reveal for this community God's liberating purposes. Second, an event may be distinguished from others by virtue of its causal role in advancing God's purposes in the world. Once again, the event need not be brought about by God in any distinctive way; one can suppose that God acts in this special event in just the way God acts everywhere, namely (on the classical account) as the creator and sustainer of a system of natural causes and free human agents. Yet this event may in fact mark a turning point in the progress of God's purposes in history. The escape of Hebrew people, according to this view, not only discloses God's intentions to humankind, it also advances God's intentions in a particularly significant way. Third, an event may be distinguished from others because God acts directly in it to turn events in a direction they would not otherwise have gone. What makes the event special is that God acts, on this occasion, to alter the course of the world's history. On this view, God not only acts indirectly through created causes and agents, God also acts directly in the world to bring about particular states of affairs. An event of this sort may or may not evoke a recognition of God's working, and it may or may not represent an especially significant turning point in the course of events, but even if it remains hidden in the minutia of history, it constitutes a particular divine action in the world.

Many modern theologians have sought to avoid this third, and strongest, claim about divine action and have interpreted traditional talk about God's acts in history exclusively in terms of the first two. This treats particular divine action as a subset of God's universal activity as creator; it incorporates the idea of divine providence entirely into the doctrine of creation. At the founding of modern Protestant theology, for example, Friedrich Schleiermacher (1768–1834) contended that God bears the same relation to every event, though some events play a special role in awakening in human beings a deepened experience of their absolute dependence upon God as the source of all things. This approach has important implications for a number of central topics in Christian theology (e.g., in giving an account of the person and work of Christ), and is a matter of controversy. There are powerful considerations that push in this direction, however, not the least of which are those derived from the impact of the natural sciences.

It has become commonplace for modern theologians to argue that a scientifically informed understanding of the world presents fatal objections to the assertion that God acts in history to affect the course of events. Rudolph Bultmann (1884–1976), for example, contended that one cannot embrace a scientific world view and also affirm that God acts within objective history. The lawful structures described by the sciences leave, in Bultmann's phrase, "no room for God's working," and any divine action will necessarily be a miraculous intervention that disrupts the natural order. Similar claims have been made by a succession of contemporary theologians. Bultmann's solution was to insist that God's action should be understood as an engagement with the human self that leaves the natural order untouched. This strategy can succeed, of course, only if one thinks that selves can be affected without altering their physical conditions, and if this idea is rejected, then it is far from clear that God can interact with embodied persons without affecting the natural world.

There are at least two considerations at work in these scientifically based worries about particular divine action. Both have to do with miracles, understood in the rather artificial but familiar modern sense of divine actions that contravene the structures of nature. The first concerns the epistemic status of claims about miracles. Although it is sometimes said that science has shown that miracles cannot occur, there is little prospect of vindicating this general claim. It is more plausible to note that scientifically literate people find their expectations about the world to have been shaped in ways that raise significant evidential barriers to accepting claims about miracles. David Hume (1711–1776) gave early and elegant expression to an argument that it will always be more reasonable to conclude that testimony about miracles is mistaken or fraudulent than to believe that a well-evidenced law of nature has been abrogated. There are also distinctively theological objections to giving miracles a pervasive role in one's account of divine action. Nonetheless, while there are good reasons for caution about claims regarding miracles, it important to note that, at least on a classical account of creation, there is no theological ground for denying that the creator of the universe is free to act in ways that exceed the causal powers of creatures.

The second issue concerns the claim that any divine action that affects the course of events will necessarily constitute a miraculous intervention in the lawful structures of nature. This conclusion may appear inevitable if one thinks of the natural order as a deterministic system; it appears that in a closed structure of sufficient finite causes, God can act either by determining the design of the structure in the initial act of creation or by miraculously intervening within it. In the modern discussion of divine action it has often been assumed that universal causal determinism has been endorsed by the natural sciences, either as result of its investigations or as a presupposition of its methods. There are good reasons not to embrace this conclusion, however. Determinism has neither been established nor refuted by the sciences to date; rather, it represents a metaphysical view that extrapolates beyond the findings of the sciences and that need not be assumed in scientific research.

A number of theologians have sought ways to conceive of particular divine actions that do not involve any disruption of the structures of nature. Arthur Peacocke (1924–) notes that the world described by the natural sciences is structured as a complex, nested hierarchy of causal systems; for example, biochemical processes operate within a cell located within an organ that functions within an organism. The higher levels of organization constrain the operation of their parts without abrogating the causal laws proper to those parts. Peacocke couples this picture of the natural order with a panentheistic conception of God according to which the world is encompassed within God, and God constitutes the ultimate whole that unites all finite systems. This opens the way to proposing whole-part as the model for God's action; God affects the world as a higher level system affects is parts, channeling their operation in particular ways without violating the lawful structures that govern them. Note that this account would allow for nonmiraculous particular divine influences upon the course of events whether or not the world constitutes a closed system of sufficient (i.e., deterministic) causes. The crucial task facing such a position is to vindicate the claim that God can affect the operations of finite causal systems without this divine influence registering as a discontinuity in the causal series.

Another strategy in developing an account of particular divine action explores the theological possibilities that arise if the universe is not in fact thoroughly deterministic in its structure. If the order of nature does not constitute a lock step of deterministic law but rather includes elements of under-determination, whether as mere chance or as self-determining freedom, then perhaps God can act in the world without in any way disrupting its inherent structures. The world that God created might, that is, incorporate both lawful regularities and openness to novel developments that are not entirely prescribed by the past.

John Polkinghorne (1930–) has proposed that the science of chaotic systems, which are highly sensitive to initial conditions and functionally unpredictable, provides a window on what may be a more supple and flexible network of relations in nature. Although these systems are described in deterministic equations, Polkinghorne notes that the laws of nature formulated by the sciences are a simplification and abstraction from the actual complexities of nature. This suggests that God might act by affecting the conditioning context within which these malleable systems operate. Other thinkers have explored the possibilities created by indeterministic interpretations of quantum mechanics. William Pollard (1911–) was the first to develop a proposal of this kind, but the idea has been explored and refined by a number of others. On what is arguably the dominant (though by no means the only) interpretation of quantum mechanics, there are transitions in quantum systems (namely, from a probabilistically described superposition of states to a determinate value for a measured variable) that have necessary but not sufficient conditions in preceding states. If the effects of these chance transitions are sometimes amplified by the larger systems in which they occur, then they can make a difference in the macroscopic course of events. Robert John Russell (1946–) has argued that this amplification can be found in a number of natural structures, notably in genetics. The structures of nature, in this case, would be open and flexible in such a way that God could, without disrupting the probabilistic regularity of those structures, act through them to bring about particular effects in the world. It might be objected that this represents a return to the God-of-the-Gaps, that is, the hasty appeal to divine action at points of scientific ignorance. In this case, however, the relevant gaps occur in nature, not simply in human knowledge of nature. If the Copenhagen Interpretation of quantum theory is correct, then the deepest structures in nature are indeterministically open, and that is a fact about the world that theological reflection will need to take into account. Of course, the viability of particular theological proposals of this sort will depend in part on developments in the relevant sciences. Given the multiple options in interpreting quantum theory and the persistence of unresolved fundamental questions within the theory itself, any theological use of this science must remain a tentative exploration of intriguing possibilities.

Conclusion

The affirmation that God acts in the world has played a central role in the theistic religious traditions, and there are a number of ways in which this idea can be understood. God acts as the creator who calls all finite things into being and sustains their existence at every moment. In this way God acts directly with every causal operation or intentional action of creatures. By virtue of endowing created things with causal powers of their own, God can be also understood to act indirectly by means of the order of nature. Theists have typically affirmed that particular events can be identified as special acts of God, at least in the sense that they play a distinctive epistemic or causal role, and perhaps also in the sense that they reflect a direct divine action that affects the course of events or the lives of individuals. The latter form of special divine action raises difficult questions of theological interpretation, and it presents one of the points at which the dialogue between religion and science has been most fascinating and fruitful.

See also CLOCKWORK UNIVERSE; COPENHAGEN INTERPRETATION; CREATIO EX NIHILO; DEISM; DETERMINISM; DOUBLE AGENCY; GOD OF THE GAPS; MIRACLE; PANENTHEISM; PROCESS THOUGHT; PROVIDENCE; SPECIAL DIVINE ACTION; SPECIAL PROVIDENCE; THEISM; WHITEHEAD, ALFRED NORTH

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THOMAS F. TRACY

DNA

DNA (*deoxyribonucleic acid*) carries design information between generations, and thus accounts for inherited biological traits (*phenotypes*). At conception, a father's sperm injects a set of DNA molecules into a mother's egg, which already contains a nearly matching set. Those molecules contain the designs for all the material components their child needs for growth, development, and daily living.

Structure of DNA

The designs are called *genes*. Some genes play a role in regulating other genes, and some design *ribonucleic acid,* a close relative of DNA. But mostly, the designs in DNA are for the class of chemicals called proteins. The human body contains tens of thousands of kinds of proteins, which do all the body's work. Interactions among those proteins, and interactions between them and environmental factors account for the processes and structures of the body. Those processes and structures are manifested as inherited traits. DNA is comprised of chains of chemical subunits called *nucleotides,* each of which contains one nitrogenous base: *adenine* (*A*), *thymine* (*T*), *cytosine* (*C*), or *guanine* (*G*). The design instructions in DNA are spelled out as particular sequences of these four bases. This is analogous to conveying instructions in printed books by particular arrangements of the twenty-six letters of the alphabet. In the case of genes, however, there are only four letters in the alphabet. Hundreds of nucleotides are linked in a DNA chain in a sequence that spells out instructions for a single gene.

There are two complementary chains in the structure of DNA. Each nucleotide in DNA has a sugar component joined to a phosphate group at one point on the sugar, and to a nitrogen-containing base attached at another point. The chains in DNA have the phosphate of one nucleotide linked to the sugar of the next nucleotide to form a strand of alternating sugars and phosphates with dangling nitrogenous bases. DNA contains two such chains, twisted around each other to form a double-stranded helix with the bases on the inside. Every *A* on one chain forms weak bonds with a *T* on the other strand, and every *C* on a strand bonds weakly to a *G* on the opposite chain. The two strands, held together weakly by the pairing of *A* with *T*, and *G* with *C*, are thus complementary, and the sequence in one can be deduced from the other's sequence.

Design information is transmitted as new DNA to new cells during development and growth. The complementarity of the two DNA strands allows their information to be copied. Each old strand is used as a template in synthesizing a new complementary one. Intricate cellular machinery makes new copies of the DNA when a fertilized egg divides into two progeny cells. When each of the progeny divides again, the new progeny all receive complete copies of the parental DNA. As the fertilized egg grows to become successively an embryo, a fetus, a child, and finally an adult, cells go through many rounds of division with replication of the DNA in each round. Finally, adult humans have trillions of cells, each one (except sperm and ovum) containing complete copies of the DNA initially contributed by the parents.

On rare occasions mutations (changes) are made in nucleotides by chemicals, radiation, or errors in copying DNA. In a nucleotide chain, one nucleotide may be substituted for another, or one or more nucleotides might be inserted or deleted. Sometimes the change in DNA structure has little or no effect on the function of the gene's product, but it frequently harms the function to some degree, or very rarely enhances it. Harmful mutations cause gene-based diseases, but enhancing mutations allow organisms to evolve new or more effective functions. Like normal phenotypes, disease phenotypes usually require the products of multiple genes, so most defective genes predispose an organism to disease rather than directly causing it. The accumulation of mutations within the human species accounts for such phenotypic differences as eye color, stature, or skin pigmentation. The number of mutations among human genes is so large that no two persons, except for identical twins, have exactly the same nucleotide sequence in the three billion bases of their DNA.

Control of gene expression

DNA information is expressed as proteins and their feedback networks. The information resident in nucleotide sequences is used not only for replicating DNA, but also for synthesizing proteins. Proteins are chains of a few hundred subunits called *amino acids,* of which there are twenty kinds. The amino acids in a protein are arranged in a specific sequence by cellular machinery that translates the genetic information coded in DNA. The sequence of nucleotides, read three at a time, corresponds to the sequence of amino acids in a protein. The amino acids differ among themselves in chemical character so that every kind of protein differs in chemical character from others. For the work of the human body many thousands of proteins are needed, each having a highly specific function like catalyzing a chemical reaction or transporting oxygen. Observable phenotypes are the result of protein action, usually the coordinated action of many proteins. The functions of many proteins are integrated into large networks, and these webs of chemical processes act as feedback control systems allowing organisms to shift the balance of their activities to adapt to changes in the demand for the system's output. Often the networks possess alternate pathways for achieving a desired output.

Differentiation into specialized cells requires the control of gene expression. The development of a human being starts with a single-celled, fertilized egg. As the egg divides into two cells, and as successive rounds of cell division occur, every progeny cell receives a complete copy of parental DNA. In the first few divisions, the cells produced are identical in all observable characteristics, but as cell division continues, cells are produced that differ in phenotype even though all the cells continue to have identical DNA. In this differentiation, particular genes are controlled by blocking their expression, not by changing nucleotide sequence. Regulatory molecules block particular sites in DNA preventing translation of the corresponding genes into their products. Specific blocking thus generates different patterns of gene expression. Changing patterns of gene expression produce distinct populations of cells, diverging in phenotype as differentiation progresses. Eventually, differentiation in humans produces more than two hundred cell types, organized into different tissues and organs. In any one cell type the majority of its approximately 35,000 genes is repressed, leaving a small subset of expressed genes that differs from the subsets expressed in other cell types. Phenotypic differences between progeny in a given cell generation depend on the location of the cells in different microenvironments. During differentiation cells adapt to a succession of environmental changes produced by changes in their neighboring cells and extracellular fluids. Each successive adaptation is superimposed on its predecessor so that each terminally differentiated cell manifests the entire history of its lineage and not merely its immediate state. Since differentiation is irreversible in animals, (except in special cases), history as well as DNA designs a person, even in the material sense.

Feedback networks and regulation of genes allow individual organisms to adapt to changing conditions throughout life. When environment increases the need for the product of a network of chemical reactions, the overall process will be accelerated, and when need decreases the process will be inhibited. Obviously, adaptation to environment is induced by contact with physical and chemical forces, but adaptation can be evoked even without physical contact, as in the adaptation of the brain through learning, and emotional reaction. Many of these adaptive responses affect patterns of gene expression, and therefore environment, as well as history, joins with DNA in designing persons.

At the level of populations, long-term adaptation to environment occurs more by changes in gene structure than by changes in the expression of genes. The mechanism for this adaptation is the natural selection that underlies evolution. For example, skin pigmentation may be an adaptation that protects against exposure to the sun, and the genes that design the pigment systems would be naturally selected in successive generations that are exposed to much sunlight. Similarly, sickle-cell hemoglobin seems to have evolved in Africa because it offers resistance to malaria that is prevalent there.

Long-term adaptation through natural selection is most obvious in the case of physical and chemical aspects of human beings. Less obvious is the adaptation of behaviors through natural selection of genes, a possibility actively studied under the title "sociobiology." Although the mechanisms producing material phenotypes may seem more obvious than those producing social behaviors, a mechanism giving rise to a certain behavior may be thoroughly materialistic, although far more complex. Behavior modification by psychoactive drugs reveals a material mechanism for behavior. A mechanism can be pictured, for example, in the courting and mating behaviors that are correlated with the release of hormones from the brain, when an animal or human senses that a potential mate is near. Those released hormones induce particular chemical reactions at many sites throughout the body, giving rise to an appropriate pattern of bodily actions. Moreover, feedback responses between the mates guide further behavioral interactions between them. The hormonal system that links brain functions to bodily functions is, of course, designed by genes, and the mechanism just sketched is clearly materialistic. The frequent association of natural selection with notions of "survival of the fittest," makes altruism an especially challenging kind of behavior to study in testing the validity of sociobiology theory, and much of the research of sociobiologists is focused on the evolution of a gene for altruism.

Genes affect behavior, but as is the case with most human phenotypes, genes act in combinations and their expression is modulated by the histories and environments of individuals, as already described. Through the invariability of individual histories and environments, natural selection must be able to recognize the difference between organisms that possess a particular behavioral gene, and those that do not possess it. In order for a behavioral gene to evolve through natural selection it must be powerful enough in determining the behavior, to avoid substantial compromise by variable non-genetic factors. Sociobiology, then, tends to favor a strongly deterministic and materialistic view of behavior.

Human nature and genetic determinism

Choosing is part of human nature, but its degree of autonomy is debated. All agree that choice is constrained by genes, history, and environment, but does any degree of freedom remain? Science describes material brain mechanisms as chains of causes and effects, but every cause is an effect having a prior cause. Since the initial cause is not recognized by science, some say thought initiation is due to chance. Others look for initiation outside the material realm of science by distinguishing between mind and brain, or even spirit and brain.

Some degree of genetic determinism is necessary in describing human nature. All the possible scenarios of a person's life must conform to the designs in DNA, and thus genes set rigid, though spacious boundaries on what a person can be and do. But genes are insufficient for explaining what actually happens. What actually happens within the boundaries set by genes, depends on factors that control genes, including environment, history, and mental state. The question arises whether spiritual forces can be added to the list of controlling factors. Material determinism argues that a complete physicochemical description of the history and state of a person would explain everything without including a spiritual component. Some, however, argue that human spirituality is a capacity that emerged as gene-based human biology evolved, and that its activity cannot be fully comprehended at the molecular level. Still others add spirit as a control factor in human nature in accepting a dualism where body and spirit are distinct, though coexistent, in a person. The disparity in these views of human nature has theological consequences.

A view of human nature according to material determinism fits atheism and deism. It provides no locus for personal interaction with God, although deists might suppose that God influences humans through environment. Belief in human spirituality, either as an emerged capacity or as a distinct part of human nature does provide such a locus. Scientific understanding of gene-based human biology does not perceive a spiritual component in human nature, but it might not be expected that a physicochemico-molecular description of humans would be capable of such discernment in the first place.

See also GENE PATENTING; GENETIC DEFECT; GENETIC DETERMINISM; GENETICS; HUMAN GENOME PROJECT; MUTATION; NATURE VERSUS NURTURE

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DOUBLE AGENCY

The idea of double agency arises in discussions of divine action through the operation of finite causes and the actions of human agents. Thomas Aquinas (c. 1225–1274) contended that God as creator is the first, or primary, cause who gives being to finite things and empowers them to act as they do. As a result, the activity of creatures is also the action of God, though God and creatures act on different levels. Claims about double agency raise particularly difficult issues when considering God's relation to free human actions. Here one must grapple with questions about whether and in what sense the act can simultaneously be ascribed to more than one agent.

See also DIVINE ACTION; PROVIDENCE; THOMAS AQUINAS

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DOWNWARD CAUSATION

When the direction of casual influence extends from "higher" levels of reality (say, above the level of physics) down to "lower" levels of reality, it is called downward causation. The ontological structure of the world may be seen as consisting of more than one domain, with each domain consisting of different entities, and with different properties defined over the respective domains. Thus Cartesian dualism envisaged a bifurcated world of two metaphysically independent domains, one containing mental substances defined by "thought" or "consciousness," and the other containing physical "stuff" defined by "extension." In contemporary emergentism the world is pictured in terms of a multilayered structure, with microphysical entities at the bottom and with higher-level entities (such as molecules, cells, organisms, and social groups) being mereologically composed of these lower-level entities, yet characterized by a set of properties distinctive of the relevant higher level. In a way, so-called nonreductive physicalism, which more or less became the received view in the philosophy of mind of the last quarter of the twentieth century, may be seen as nothing but a modern application of classical emergentism within the philosophy of mind. Although it holds that, ontologically speaking, all there is are physical entities and mereological aggregates thereof, it argues that psychological properties are irreducibly distinct from the underlying physical and biological properties.

Regarding such stratified ontologies, two questions naturally arise. First, there is the question of whether higher-level processes may causally interact amongst each other. Secondly, there is the closely related question of whether higher-level processes may also exert "downward" causal influence on events occurring at lower-levels of reality. Indeed, this so-called *downward* (or *top-down*) *causation* may hold special interest from a theological perspective, since the very possibility of divine action may plausibly be seen as dependent on the possibility of downward causation. It has been argued that the first question inherits whatever problems may attach to the second, which is the more crucial of the two. Thus Jaegwon Kim has claimed that *same-level* causation can occur only if *cross-level* causation can occur. Accordingly, downward causation is essential to most of the stratified ontologies under consideration.

The concept of downward causation allegedly runs into serious difficulties. Specifically, there are problematic implications of the idea implied in downward causation; for example, that higher-level processes, once having emerged from lower-level physical processes, biological processes, and so on, would somehow take on a causal life of their own down to the point of actually interfering in the underlying chain of physical causes and events. If, say, emergent mental properties are irreducibly distinct from physical properties (as maintained in emergentism and non-reductive physicalism alike), and if instances of these mental properties may be independent higher-level causes and effects of lower-level physical (e.g., bodily) events, then some physical events cannot be fully explained in terms of physical antecedents and laws alone. This result, however, would violate two highly respected and important philosophical principles: the principle of the causal closure of the physical domain and the closely related principle of the completeness of physics. That is to say, assuming causal interaction between higher-level processes on the one hand and processes at the basic level of physics on the other (as presupposed in all of the above philosophies with stratified ontologies), there can no longer be a complete physical theory of physical phenomena.

An alternative account of the relation between various ontological levels may be possible, allowing one to avoid the above dilemma. Levels of reality are not just related by the mereological relation of being *part of.* That would render organisms mere aggregates of cells, and cells mere aggregates of molecules. In addition they are related by higher-level principles organizing lower-level events into systemic patterns of interaction. As a result, certain context-dependent causal pathways of physical activities will be selectively activated, rather than others. In view of this alternative relationship of so-called multiple *supervenience,* causal processes may come to be seen as highly patterned systemic processes discernible only at higher levels of reality.

Reflecting upon this relationship of multiple supervenience may thus make clear that higher-level patterns of organization are themselves genuine causal factors actually operative in channeling and orchestrating the lower-level flux of microphysical events to yield stable recurrent patterns of macrocausation that are self-sustaining or self-reproducing as a result of the systemic organization of their parts. In other words, given multiple supervenience, downward causation will occur in consonance with the principles of physics, rather than in violation of them. To believe in downward causation, therefore, need not be tantamount to a belief in brutely emergent fundamental laws proprietary to a certain level of intricately organized systems of physical events and processes, such as organisms or minds, with concomitant causal interference at lower levels of organization in violation of the laws of microphysics. Hence, downward causation may be assigned a stable place in the picture of how the world is organized without upsetting the conception of the various domains of physics as constituting a closed and complete system of physical events at the physical level of description.

See also CAUSALITY, PRIMARY AND SECONDARY; CAUSATION; DIVINE ACTION; PHYSICALISM, REDUCTIVE AND NONREDUCTIVE; SUPERVENIENCE

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DUALISM

This term *dualism* is used to describe any system in which there are two realities. The term is sometimes used to express the existence of two gods or the existence of God and the cosmos, but its most common usage is in the philosophy of human nature. A dualist holds that a human person is constituted by a body and what may be called a mind or soul or consciousness. Some dualists hold that persons are nonphysical concrete subjects who are embodied contingently. That is, a person may survive the destruction of his or her body, or one's body may continue to exist (as a corpse) after one has ceased to be. The greatest competing philosophy of human nature is *materialism.* While representatives of dualism in contemporary philosophy are in the minority, dualism is not easily uprooted philosophically, religiously, or culturally.

On the philosophical front, materialists often have difficulty capturing the evident existence of consciousness or felt experiences. Human thinking, sensing, and feeling appear to be different in kind from brain processes and other bodily activity. At a minimum, there is a profound causal relation between the two (one's thinking is contingent on neurological events), and yet a causal relation is not the same thing as identity. The mental and physical may be causally interdependent without being identical. Since 1980, a range of philosophers who are materialists either in their convictions or inclinations (e.g., Thomas Nagel, Colin McGinn, Jaegwon Kim, and John Pollock), have insisted that there are serious problems with identifying consciousness with physical states and processes.

A shift in contemporary science has also bolstered the case for dualism. So long as a strictly deterministic physical science dominated the view of nature, it appeared that something nonphysical (states of consciousness or the soul) would have no causal role in explaining events in the world. This would render a dualist account of action absurd. But quantum mechanics has advanced an indeterminist view of the cosmos, and it is more difficult to rule out dualism.

From a religious point of view, dualism is in play with most but not all traditions that acknowledge an afterlife. Some religions believe in a resurrection of the dead in which a person survives death by their material body being either reconstituted or re-created. But even these religions often preserve some immaterial locus or referent to secure a person's identity; in between physical death and resurrection a person might still be thought of as present to God. Virtually all religions that include a belief in reincarnation allow that there is some immaterial aspect to a person's or a soul's identity. If persons are identical with their bodies, then what happens to persons and bodies are the very same; dualism allows persons and souls to share a different fate from their bodies.

Dualism also receives some support from cultures that routinely adopt different methods for studying and talking about persons as opposed to studying and talking about their bodies. Consider a modest example in English: It can make sense to say that someone is in class but that his or her mind is far away.

History of the concept

Historically, the ancient Greek philosopher Plato (428–347 B.C.E.) was a key advocate of a form of dualism. Dualism is integral to his case for the immortality of the soul, as expressed in the *Phaedrus, Phaedo,* and *Republic*. Plato posited not just a postmortem existence but life before material embodiment (prenatal existence). Plato thought of a person's material embodiment as good but also as something that impedes the soul's longing for the good, the true, and the beautiful. Compared with the beauty and glory of disembodied life, material existence can be like a prison. The early Christian leader Augustine of Hippo (354–430 C.E.) developed a Platonic form of Christianity, rejecting some of Plato's beliefs (Augustine rejected pre-natal existence, as well as Plato's view of the divine as a finite reality) but preserving his dualism and the centrality of the good.

Some Platonic Christians in the medieval period speculated that God creates a host of various forms of intelligence in either embodied or disembodied form. This formed part of the principle of plentitude in medieval thought. The philosopher Thomas Aquinas (1225–1274) preserved much of the Platonic, Augustinian tradition but he more firmly insisted that human beings are comprised of matter and form. He still allowed that a person's soul persists after death, so Aquinas's reservations about radical dualism were limited.

Modern philosophy in Europe focussed on three philosophies of human nature. Dualism was championed by René Descartes (1596–1650); Cartesian dualism was advanced based on the conceivability of the self without the body. Thomas Hobbes (1588–1679) was very much on the other side. According to Hobbes, only matter exists and the very notion of there being something immaterial was nonsense. Hobbes insisted that even God is a material reality. A third position was championed by George Berkeley (1685–1753) who held that matter was not a fundamental, mind-independent reality. The cosmos is made up of minds and their sensory experiences. Berkeley's thesis that only minds and their states and activities exist is called *idealism*. In the eighteenth century it was possible to see dualism as a mediating, moderate choice between the extremes of materialism and idealism.

Many contemporary Christian theologians see dualism as part of an undesirable body-hatred;

dualism is accused of foisting on people an excessively fragmented view of embodiment. Moreover, dualism is thought to reflect a vain attempt by humans to distinguish themselves from the rest of creation. These objections all seem answerable. There is no necessity for dualists to see embodiment in negative terms. And while a person's psychological and physical life can be fragmented, there is no need for dualism to regard human embodiment as always laden with bifurcation. Dualists may see the embodied person as a functional unity. As for the question of human pride, Descartes famously denied nonhuman animals were like humans in possessing (or being) minds. Descartes read nature in mechanical terms while he tried to secure an exception for human life. But most contemporary dualists see the emergence of consciousness as something involving nonhuman animal life; people share with some nonhumans in having experiences and possessing psychological abilities. Dualists tend to see the emergence of consciousness as something that prevails throughout the animal world and not something limited exclusively to human beings.

See also AUGUSTINE; EMBODIMENT; MATERIALISM; MIND-BODY THEORIES; MIND-BRAIN INTERACTION; MONISM; PLATO; THOMAS AQUINAS

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E

ECOFEMINISM

The term *ecofeminism* was first used by French radical feminist Françoise d'Eaubonne (b. 1920) in 1974 to synthesize two movements previously thought of as separate: ecology and feminism. D'Eaubonne saw clear interconnections between the domination of women and that of nature, and she hoped, by making these interconnections explicit, to rescue the planet from the destructive effects of "the male system" and restore it for the benefit of humanity's future.

Ecofeminism offers a range of theoretical positions in which the prefix *eco* signifies the whole household of life. These positions include stringent critiques of reductionist ecological science because of its destructive effects on the whole. Ecofeminism is defined, however, by politically and socially multivalent feminist analyses that seek a positive understanding of the dialectic between nature and humanity in order to move beyond masculine domination of both women and nature.

The relationship between nature and human culture remains problematic for ecofeminists because the feminization of nature has contributed conceptually to downgrading women's cultural role and status. Ecofeminists reject a male elite model of human culture that inferiorizes and excludes groups of people, as well as nature. Within industrially developed societies, ecofeminists debate the issue of gender difference within cultures in dialogue with movements such as deep ecology, antimilitarism, animal liberation, antiracism, and environmental justice. Globally, ecofeminists consistently critique the environmental effects of gendered science and resource management, together with economic development models that have a disproportionate and often disastrous impact on women.

Ecofeminism also offers a potentially transformative philosophy of the self and of society. Influenced by process thought and Gaia science, every entity is seen as internally related to all aspects of its environment, with that relationship as part of what the entity is in itself. This awareness of ecological interdependence calls for an essentially nonviolent ethic of care within societies. It includes care for the fundamental elements of life in recognition of their limits, as well as attention to their present and future ecological and social costs.

Worldwide, ecofeminism focuses on relationships between global economic policies and global ecological crises, arguing that addressing the first in the form of a radical transformation of capitalist production, from an overwhelmingly competitive system to a cooperative one, benefits the global environment. Therefore ecofeminists unite with social justice organizations in order to reach out and care for those statistically most at risk from, but powerless to avert, environmental degradation: the poor, women, children, and indigenous peoples.

Ecofeminism encourages, indeed, requires a reshaping of the image of God from a hierarchical God above and beyond Earth to one continuously involved with, while not confined by, the evolutionary history of life on Earth. Therefore, ecofeminism fosters a sense of our belonging within, rather than being in control of, the community of life. The insights of process theology, feminist theology, non-traditional spiritualities, and the spiritualities of indigenous communities with a strong matriarchal tradition are used to highlight ecological interdependence and the value of biodiversity in all its forms. Many of these insights demonstrate a diversity of response to what is called sacred or divine.

See also ANIMAL RIGHTS; DEEP ECOLOGY; ECOLOGY; ECOLOGY, ETHICS OF; ECOLOGY, RELIGIOUS AND PHILOSOPHICAL ASPECTS; ECOLOGY, SCIENCE OF; ECOTHEOLOGY; FEMINISMS AND SCIENCE; FEMINIST COSMOLOGY; FEMINIST THEOLOGY; GAIA HYPOTHESIS; WOMANIST THEOLOGY

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ECOLOGY

The term *ecology* is, etymologically, the logic of living creatures in their homes, a word suggestively related to *ecumenical,* with common roots in the Greek *oikos,* the inhabited world. Named in 1866 by German biologist Ernst Haeckel (1834–1919), ecology is a biological science like molecular biology or evolutionary theory, though often thought to be less mature. Ecosystems are complicated; experiments are difficult on these open systems, often large, that resist analysis. Ecology has nevertheless been thrust into the public arena, with the advent of the ecological crisis. Ecology has also become increasingly global, and still more complex, as when planetary carbon dioxide cycles affect climate change.

Ethics, policy, theology, and ecology

Ecology mixes with ethics, an ecological (or environmental) ethics urging that humans ought to find a lifestyle more respectful of, or harmonious with, nature. Ethics, which seeks a satisfactory fit for humans in their communities, has traditionally dwelt on justice, fairness, love, rights, or peace, settling disputes of right and wrong that arise among humans. Ethics now also concerns the troubled planet, its fauna, flora, species, and ecosystems.

American forester Aldo Leopold urged a new commandment in "The Land Ethic," a chapter in his 1968 book *A Sand County Almanac*: "A thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community. It is wrong when it tends otherwise" (pp. 224–225). Since the United Nations Conference on Environment and Development, held in 1992 in Rio de Janeiro, Brazil, the focus of environmental policy, often referred to as ecosystem management, has been a sustainable economy based on a sustainable biosphere.

Theologians have argued that religion needs to pay more attention to ecology, and perhaps also vice versa. Partly this is in response to allegations that Christians view humans as having God-given dominion over nature; they dominate nature and are responsible for the ecological crisis. An ecological theology may hope to find norms directly in ecological science, but often an ecological perspective rather freely borrows and adapts various goods thought to be found in ecology into human social affairs, such as wholeness, interrelatedness, balance, harmony, efficiency, embodiment, dynamism, naturalness, and sustainability.

Leading concepts in ecological science

Leading concepts in ecology involve ecosystems, succession of communities rejuvenated by disturbances, energy flow, niches and habitats, food chains and webs, carrying capacity, populations and survival rates, diversity, and stability. A main claim is that every organism is what it is where it is because its place is essential to its being; the "skin-out" environment is as vital as the "skin-in" metabolisms. Early ecologists favored ideas such as homeostasis and equilibrium. Contemporary ecologists emphasize a greater role for contingency or even chaos. Others emphasize self-organizing systems (*autopoiesis*), also an ancient idea: "The earth produces of itself [Greek: automatically]" (Luke 4:28). Some find that natural selection on the edge of chaos offers the greatest possibility for self-organization and survival in changing environments, often also passing over to self-transformation.

The stability of ecosystems is dynamic, not a frozen sameness, and may differ with particular systems and depend on the level of analysis. There are perennial processes—wind, rain, soil, photosynthesis, competition, predation, symbiosis, trophic pyramids or food chains, and networks. Ecosystems may wander or be stable within bounds. When unusual disturbances come, ecosystems can be displaced beyond recovery of their former patterns. Then they settle into new equilibria. Ecosystems are always on historical trajectory, a dynamism of chaos and order entwined.

Michael E. Soulé and Gary Lease have demonstrated in their 1995 book, *Reinventing Nature? Responses to Postmodern Deconstruction,* that ecology as a science has not proven immune from postmodernist and deconstructionist claims that science in all its forms—astrophysics to ecology—is a cultural construct of the Enlightenment West. Science is pragmatic and enables scientific cultures to get what they want out of nature; science is not descriptive of what nature is really like, apart from humans and their biases and preferences. According to this view, humans should make no pretensions to know what nature is like without them, but can choose what it is like to interact with nature, living harmoniously with it, which will result in a higher quality life. This fits well with a bioregional perspective. Environmental ethics is as much applied geography as it is pure ecology.

Some interpreters, such as Mark Sagoff, conclude that human environmental policy cannot be drawn from nature. Ecology, a piecemeal science in their estimation, can, at best, offer generalizations of regional or local scope, and supply various tools (such as eutrophication of lakes, keystone species, nutrient recycling, niches, succession) for whatever the particular circumstances at hand. Humans ought to step in with our management objectives and reshape the ecosystems we inhabit consonant with our cultural goals.

Other interpreters, such as David Pimentel, Laura Westra, and Reed Noss, argue that human life does and ought to include nature and culture entwined, humans as part of, rather than apart from, their ecosystems. Ecosystems are dependable life support systems. There is a kind of order that arises spontaneously and systematically when many self-actualizing units interactively pursue their own programs, each doing its own thing and forced into informed co-action with other units.

In culture, the logic of language or the integrated connections of the market are examples of such co-action. We legitimately respect cultural heritages, such as Judaism or Christianity, or democracy or science, none of which are centrally controlled processes, all of which mix elements of integrity and dependability with dynamic change, even surprise and unpredictability. We might wish for "integrity, stability, and beauty" in democracy or science, without denying the elements of pluralism, dynamism, contingency, and historical development.

Ecosystems, though likewise complex, open, and decentralized, are orderly and predictable enough to make ecological science possible—and also to make possible an ethics respecting these dynamic, creative, vital processes. The fauna and flora originally in place, independently of humans, will with high probability be species naturally selected for their adaptive fits, as evolutionary and ecological theory both teach. Misfits go extinct and unstable ecosystems collapse and are replaced by more stable or resilient ones (perhaps rejuvenated by chaos or upset by catastrophe).

This ecosystemic nature, once flourishing independently and for millennia continuing along with humans, has in the last one hundred years come under increasing jeopardy—variously described as a threat to ecosystem health, integrity, or quality.

Ecosystem management

Since the 1990s, emphasis has been ecosystem management. This approach appeals alike to scientists, who see the need for understanding ecosystems objectively and for applied technologies, and also to humanists, who find that humans are cultural animals who rebuild their environments and who desire benefits for people. The combined ecosystem/management policy promises to operate at system-wide levels, presumably to manage for indefinite sustainability, alike of ecosystems and their outputs. Such management connects with the idea of nature as "natural resources" at the same time that it has a "respect nature" dimension. Christian ethicists note that the secular word "manage" is a stand-in for the earlier theological word "steward." Adam was placed in the garden "to till and keep it" (Gen. 2:15).

Pristine natural systems no longer exist anywhere on Earth (the insecticide DDT has been found in penguins in Antarctica). Perhaps 95 percent of a landscape will be rebuilt for culture, considering lands plowed and grazed, forests managed, rivers dammed, and so on. Still, only about 25 percent of the land, in most nations, is under permanent agriculture; a large percentage is more or less rural, still with some processes of wild nature taking place. The twenty-first century promises an escalation of development that threatens both the sustainability of landscapes supporting culture as well as their intrinsic integrity.

Scientists and ethicists alike have traditionally divided their disciplines into realms of the "is" and the "ought." No study of nature can tell humans what ought to happen. This neat division has been challenged by ecologists and their philosophical and theological interpreters. The analysis here first distinguishes between interhuman ethics and environmental ethics. The claim that nature ought sometimes to be taken as norm within environmental ethics is not to be confused with a different claim, that nature teaches us how we ought to behave toward each other. Nature as moral tutor has always been, and remains, doubtful ethics. Compassion and charity, justice and honesty, are not virtues found in wild nature. There is no way to derive any of the familiar moral maxims from nature: "One ought to keep promises." "Do to others as you would have them do to you." "Do not cause needless suffering." No natural decalogue endorses the Ten Commandments.

But, continuing the analysis, there may be goods (values) in nature with which humans ought to conform. Animals, plants, and species, integrated into ecosystems, may embody values that, though nonmoral, count morally when moral agents encounter these. To grant that morality emerges in human beings out of nonmoral nature does not settle the question whether we, who are moral, should sometimes orient our conduct in accord with value there. Theologians will add that God bade Earth bring forth its swarming kinds and found this genesis very good. Palestine was a promised land; Earth is a promising planet, but only if its ecologies globally form a biosphere.

Environmental science can inform environmental ethics in subtle ways. Scientists describe the "order," "dynamic stability," and "diversity" in these biotic "communities." They describe "interdependence," or speak of "health" or "integrity," perhaps of their "resilience" or "efficiency." Scientists describe the "adapted fit" that organisms have in their niches. They describe an ecosystem as "flourishing," as "self-organizing." Strictly interpreted, these are only descriptive terms; and yet often they are already quasi-evaluative terms, perhaps not always so but often enough that by the time the descriptions of ecosystems are in, some values are already there. In this sense, ecology is rather like medical science, with therapeutic purpose, seeking such flourishing health.

Ecology in classical religions

Is there ecological wisdom in the classical religions? Religion and science have to be carefully delineated, each in its own domain. One makes a mistake to ask about technical ecology in the Bible (such as the Lotka-Volterra equations, dealing with population size and carrying capacity). But ecology is a science at native range. Residents on landscapes live immersed in their local ecology. At the pragmatic ranges of the sower who sows, waits for the seed to grow, and reaps the harvest, the Hebrews knew their landscape. Abraham and Lot, and later Jacob and Esau, dispersed their flocks and herds because "the land could not support both of them dwelling together" (Gen. 13:2-13; 36:6-8). There were too many sheep and goats eating the sparse grasses and shrubs of their semi-arid landscape, and these nomads recognized this. They were exceeding the carrying capacity, ecologists now say.

Here academic ecologists can learn a great deal from people indigenous to a landscape for centuries. Such ecological wisdom might be as readily found with the Arunta in Australia, or with the Navajos in the American Southwest on their landscapes. This would be indigenous wisdom rather than divine revelation. Such wisdom is often supported more by mythology than by science. Such wisdom is also frequently mixed with error and misunderstanding.

Christian (and other) ethicists can with considerable plausibility make the claim that neither conservation, nor a sustainable biosphere, nor sustainable development, nor any other harmony between humans and nature can be gained until persons learn to use the earth both justly and charitably. Those twin concepts are not found either in wild nature or in any science that studies nature. They must be grounded in some ethical authority, and this has classically been religious.

One needs human ecology, humane ecology, and this requires insight more into human nature than into wild nature. True, humans cannot know the right way to act if they are ignorant of the causal outcomes in the natural systems they modify—for example, the carrying capacity of the Bethel-Ai rangeland in the hill country of Judaea. But there must be more. The Hebrews were convinced that they were given a blessing with a mandate. The land flows with milk and honey (assuming good land husbandry) if and only if there is obedience to Torah. Abraham said to Lot, "Let there be no strife between me and you, and between your herdsmen and my herdsmen" (Gen. 13:8), and they partitioned the common good equitably among themselves. The Hebrews also include the fauna within their covenant. "Behold I establish my covenant with you and your descendants after you, and with every living creature that is with you, the birds, the cattle, and every beast of the earth with you" (Gen. 9:5). In modern terms, the covenant was both ecumenical and ecological.

See also ANIMAL RIGHTS; AUTOPOIESIS; CHAOS THEORY; DEEP ECOLOGY; ECOFEMINISM; ECOLOGY, ETHICS OF; ECOLOGY, RELIGIOUS AND PHILOSOPHICAL ASPECTS; ECOLOGY, SCIENCE OF; ECOTHEOLOGY; FEMINISM AND SCIENCE; FEMINIST COSMOLOGY; FEMINIST THEOLOGY; GAIA HYPOTHESIS; WOMANIST THEOLOGY

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ECOLOGY, ETHICS OF

Ecological (or environmental) ethics is the study of what humans, individually and corporately, ought to value, ought to be, and ought to do in relationships with all other beings and elements in the biosphere. As in normative ethics generally, ecological ethics involves evaluating, justifying (or not), and prescribing values, norms, and standards of character and conduct in view of the ecological conditions that contribute to the well-being of humans and other life forms. This discipline is diverse in types, methods, values, problems, foundational perspectives, and other elements of ethics. Ecological ethics comes in both philosophical and religious versions; the problems and values are often the same, though the methods and ultimate rationales are often different.

The topical agenda of ecological ethics is molded by contemporary environmental problems. The primary concerns are climate change, multiple forms of pollution, human population growth, scarcities of some renewable and nonrenewable resources, human-induced losses in biodiversity, the interactive dynamics of ecological degradation and economic patterns of consumption and distribution, and, increasingly relevant, the environmental effects of genetic manipulations.

Models and value systems

Much ethical thought about the environment has been an expansion of the concern in traditional ethics to cover the adverse effects of environmental conditions on human interests. Classical moral values and norms remain basically unchanged. Only humans count for direct moral consideration. Other life forms are strictly instrumental values—means—for human needs and wants, such as scientific, aesthetic, and various economic purposes. The basic moral assumption has been: Humans ought to take care of the environment so that the environment can take care of humans.

In reaction to this anthropocentric model, the clear majority of contemporary ecological ethicists interpret their discipline as a reformation of moral values and duties. The bounds and rules of relationships are reshaped by a new consciousness of three fundamental facts about planetary existence: the biological, coevolutionary kinship of all life forms; the systemic interdependence of all beings and elements; and the biophysical limits of all planetary goods. Ethics itself must change to fit the reality that humans are not only social animals, as recognized in classical ethics, but also ecological animals.

Consequently, a prominent feature—some, indeed, would say a defining feature—of ecological ethics is the extension of moral standing beyond the human community. The questions are perplexing: Who or what has moral claims on humans for consideration of their interests? Are animals, plants, and other biological classes included? What about individuals, species, and ecosystems as the holistic interactions among organisms and elements? Where is the line to be drawn, if at all? What are the justifications or reasons for recognizing moral status?

Some ethicists limit this extension to organisms that satisfy certain criteria, such as sentience in the case of animal rights advocates. Critics claim, however, that this limitation leaves the vast majority of the biota with the instrumental status of “things.”

Most ecological ethicists now argue that all organisms have some moral claims on humans, because they are intrinsic values, goods, or ends for themselves. Many contend that species also have moral claims as genetic lifelines that carry these values. Only a few argue for equal value among species; most allow for graded valuations in accord with significant and relevant differences. An increasing number also claim that ecosystems are values for themselves that warrant direct moral consideration.

At this point, the field is split between so-called biocentric and ecocentric value systems—or, more accurately, individualistic and holistic perspectives on moral duties. The debate is sometimes confused and polemical. Biocentrists focus on protecting or promoting the welfare of individual lives, often mammals, but sometimes other species, in a given context. Ecocentrists stress systemic values, arguing that our primary or only responsibility is to the integrity of ecosystems.

These positions, however, need not be mutually exclusive. For a fully adequate ecological ethics, some in the field propose, we need a basis for respecting both life forms (individuals, populations, and species) and collective connections—that is, diverse and whole ecosystems in a healthy ecosphere, which alone provide the essential conditions for the good of all individuals and species. The individualistic and holistic poles may not be contraries but rather complementary sides of a comprehensive ecological ethics.

Sustainability

Sustainability has been a prominent norm in ecological ethics—largely because of the perception that present patterns of using the planet as source and sink are unsustainable. Sustainability is living within the bounds of the regenerative, assimilative, and carrying capacities of the planet indefinitely, in fairness to future generations. It seeks a just distribution of goods between present and future generations, without sacrificing one for the other. Human beings have obligations to future generations because what they are and do will have profound effects on them for good and ill. Since they do not yet exist but can reasonably be expected to do so, future generations can be said to have anticipatory rights, and every present generation has anticipatory obligations to them.

Sustainability is often interpreted as an anthropocentric norm, but that limitation is not at all inherent in the idea. Ecological ethicists usually interpret sustainability as responsibilities to future generations of both humankind and other kinds. This inclusive vision may significantly change the prevailing principles and practices of sustainability.

Reflecting practitioners' commitments to sustainability, social equity, and ecological integrity, two issues have been prominent on the agenda of ecological ethics: high levels of human population and consumption. From an ecological perspective, these are intertwined problems. Population and consumption are two interactive sides of a species' impact on its environmental base, whether by too many humans contending over a depleted base or by an economic elite using that base disproportionately. The basic moral questions are: What are the responsibilities of humans, individually and collectively, to the rest of humanity, other species, and future generations? What then are the material and demographic conditions that humans must respect to fulfill these responsibilities? Ecological ethicists frequently urge moral limits on both economic consumption and sexual reproduction for the sake of the social and ecological common good.

Conclusion

From the perspective of ecological ethicists, their discipline is not another branch or subdiscipline of ethics, such as medical or business ethics. It is rather the expansion of every branch of ethics, the wider context for every ethical focus. Business ethics, for example, must now think not only socially and economically, but also ecologically—considering moral responsibilities to other life forms and their habitats, present and future, in economic planning. Henceforth, all ethics must be done in the context of ecological ethics—or else they will be distorted and constricted ethics.

The intention of ecological ethicists, with rare exceptions, is not to substitute biotic values for anthropic ones, but rather to weave these two sets together coherently for the enhancement of both—in short, to integrate the quests for social justice and ecological integrity, for the present and future.

See also ANIMAL RIGHTS; DEEP ECOLOGY; ECOFEMINISM; ECOLOGY; ECOLOGY, RELIGIOUS AND PHILOSOPHICAL ASPECTS; ECOLOGY, SCIENCE OF; ECOTHEOLOGY; GAIA HYPOTHESIS; FEMINISMS AND SCIENCE; FEMINIST COSMOLOGY; FEMINIST THEOLOGY; WOMANIST THEOLOGY

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JAMES A. NASH

ECOLOGY, RELIGIOUS AND PHILOSOPHICAL ASPECTS

The word *ecology* has two meanings. It refers to a discipline within biology that studies ecosystems, and it refers to the ecosystems that biologists study. These ecosystems can include the local biotic communities with which, for example, indigenous peoples and farmers often have special bonds. But the concept of ecosystem can also apply to the whole of the Earth and the whole of the cosmos.

To call these larger wholes "ecosystems" is not to suggest that they are static or stable. Indeed, even local biotic communities are not static. Contemporary ecologists say that such communities are evolving and naturally subject to dramatic and sometimes chaotic changes, as is the larger whole, which scientists call the universe.

Religious people have different names for this larger and more inclusive whole. Jews, Christians, and Muslims often speak of the integrated whole as "the creation" and its ongoing development as "continuing creation." They say that creation includes the heavens as well as the Earth, that it has invisible as well as visible dimensions, and that humans are a part of, not apart from, this larger whole. Some Jews, Christians, and Muslims believe that the future of this whole is already determined by God, quite apart from decisions made in the present. Others believe that the future, at least of the Earth, is not yet determined and depends on present decisions. Religion, like science, has its determinists and nondeterminists.

For many religious people, it is the smaller ecosystems—the bioregions and their many forms of life on planet Earth—that are of greatest immediate concern. Environmental crises have prompted their concerns. They have been forced to ask: In what ways does my religion encourage or discourage healthy ways of (1) behaving toward, (2) thinking about, and (3) apprehending landscapes, life-support systems, and other forms of life?

On this matter Buddhist environmentalism is especially instructive. It does not speak of the universe as creation; rather it presents the universe as a beginningless and endless series of cosmic epochs. But Buddhist environmentalism points out that a healthy religious approach to nature includes all three forms of response just named: (1) moral conduct toward other living beings, (2) intellectual understanding of the interconnectedness of all things, and (3) mindful awareness of other living beings, on their own terms and for their own sakes, without projection. It emphasizes that mindful awareness can be nurtured, not simply by reading books about ecology, but by meditation and direct exposure to the palpable presences of the Earth.

Can science help religion?

As religious people face environmental crises, they can simultaneously ask: How might insights and information from the ecological sciences, and from other forms of science as well, help my religion to become more responsible and sensitive than it might otherwise be? The response is twofold.

On the one hand, most religious people realize that science provides relevant information that can help people make wise decisions in terms of land use, population, and pollution control. Additionally, some appreciate ways in which science can help humans better understand human continuities with other forms of life, both genetically and evolutionarily; better understand the interconnected nature of the whole of reality, as is affirmed in many Buddhist, Daoist, and Confucian points of view; and better understand that the Earth and cosmos are creative, containing potentialities for creative adaptation and renewal, even when things seem hopeless. Finally, some ecologically minded and religiously interested writers, Thomas Berry and Ursula Goodenough, for example, propose that science offers a common epic—the epic of evolution—that can itself inspire a sense of purpose and adventure, leading people to realize that "the great work" of our time is to help create mutually enhancing bonds between humans and the rest of the Earth.

On the other hand, many ecologically minded religious people simultaneously reject certain forms of materialism and reductionism that are characteristic of some but not all science. Particularly problematic are those (1) that reduce galactic and biological evolution to an amoral and purposeless process devoid of intrinsic worth or any capacity for divine guidance; (2) that insist that scientific ways of knowing—and those alone—provide wisdom concerning nature; and (3) that reduce living wholes—animals who are subjects of their own lives, for example—to mechanical wholes devoid of subjectivity and creativity. These rejections suggest that religious approaches to ecology, particularly at the level of worldview, will often differ from scientific approaches, even as they learn from science.

Ecotheologies and ecophilosophies

As religious people face the environmental crises, they are led to develop what are often called *ecotheologies* or *ecophilosophies.* Typically these theologies and philosophies explore the histories of religious traditions for usable insights and practices, criticize those aspects of the past that seem problematic rather than helpful, and develop new ideas that build upon, but also move beyond, inherited ways of acting, thinking, and feeling.

The development of these perspectives has been underway for several decades, but it has been catalyzed and brought into focus by work done at the Center for the Study of World Religions at Harvard University in Cambridge, Massachusetts, in collaboration with the Center for Respect of Life and Environment in Washington, D.C., and Bucknell University in Lewisburg, Pennsylvania. From May 1996 until July 1998, the Center for the Study of World Religions hosted a series of ten conferences, each involving scholars from the world's religions, all of which "explored particular intellectual and symbolic resources of a specific religious tradition regarding views of nature, ritual practices, and ethical constructs in relation to nature" (Tucker). The scholarly anthologies produced by these conferences offer a multivolume anthology on world religions and ecology.

Equally important is the work being done by creative scholars from the thousands of small scale, indigenous societies in the world, including Native American, African, Aboriginal, and South Asian. The religions of these peoples are indistinguishable from their cultures and there is much variation among them. Still, it is generally recognized, by scholars of classical religions and by representatives of indigenous traditions themselves, that the life-ways of indigenous peoples emphasize reciprocal relations between human beings and their local bioregions in ways that are more typically absent from classical traditions. The Harvard series included a conference on iIndigenous traditions, highlighting ways in which, even as these peoples offer no technological fixes for modern problems, they nevertheless offer examples of "a loving experience of place" from which many can learn.

Also important to religion and ecology is the work of philosophers around the world, some affiliated with religions and some not, who have simultaneously explored and criticized the past, and simultaneously developed new perspectives emphasizing human embeddedness in the larger web of life. Deep ecology and ecofeminist philosophies are prime examples. While some versions of these perspectives are philosophical rather than religious if the word *religion* implies allegiance to a classical religious tradition, all are religious in the sense that they are interested in helping guide humans toward sensitive ways of perceiving and responding to nature.

All of these ecotheologies and ecophilosophies have their distinctive features. Ecotheologies emerging out of the Abrahamic traditions often emphasize:

(1) that human beings are a part of, not apart from, a larger evolving whole;

(2) that they are kin to fellow creatures on Earth;

(3) that the whole of creation, including Earth, is embraced by a surrounding presence, namely God, who cares about the whole of creation and each living being within it;

(4) that God calls humans to embody alternatives to the more greed-driven lifestyles of consumer society;

(5) that God calls humans to be good stewards of the Earth and compassionate participants in the ongoing development of creation.

This compassionate participation involves commitment to four values advocated by "The Earth Charter": respect and care for the community of life; ecological integrity; social and economic justice; and nonviolence, democracy, and peace.

Among the Abrahamic ecotheologies that stress these five ways of thinking, process theology is especially important for people interested in the dialogue between religion and ecology; although it is environmentalist in orientation, it draws deeply from quantum theory, ecological biology, and evolutionary biology. It is an especially science-based form of contemporary ecotheology. It is also important because it wrestles with the reality of suffering in creation, proposing that the God who calls humans toward environmental responsibility is a counter-entropic and influential lure within creation, who is nevertheless not all-powerful in the classical sense of having unilateral power. From the perspective of process theology, the very God who calls toward compassion is a God who shares in the suffering of all creation and who is impoverished by a reduction in the Earth's biological diversity. The Earth and the whole of the universe is God's body.

Ecophilosophies emerging out of the various East Asian and South Asian traditions do not emphasize the role of God, but rather ground their commitments to a sustainable future in a deep sense of interconnectedness that is likewise consonant with many dimensions of science. To this emphasis on interconnectedness, they also add the importance of mindfulness in the present moment and the importance of having a nongrasping approach to life that allows other living beings simply "to be" without "being exploited." Here nonattachment does not mean nonappreciation, but rather nongrasping, precisely so that other living beings and the rest of nature can be appreciated on its own terms, without being a mere "commodity" for the consumer-driven mindset. With this emphasis they add to the critique of consumerism likewise offered by Abrahamic ecotheologians.

The deep ecology perspective and ecofeminist orientations add distinctive but complementary emphases to the Abrahamic and Asian perspectives just noted. Not unlike Buddhism, deep ecology emphasizes the notion of an ecological self whose inner horizons transcend the illusion of a skin-encapsulated ego and live from a deeper sense of kinship with the whole. Ecofeminism adds that the very illusion of a skin-encapsulated ego is often grounded in patriarchal habits of thought and feeling.

In short, the environmental crisis stimulates a great deal of work within religions and among those interested in religiously based alternatives to consumerist habits of thought and feeling. Some but not all of this work is enriched by insights from the sciences, even as some but not all is also critical of certain dimensions of science, especially its reductionistic and more determinist strands. The dialogue between religion and science involves a dialogue with the Earth, with which both religion and science are jointly and sometimes collaboratively engaged.

See also ANIMAL RIGHTS; BUDDHISM; CHINESE RELIGIONS, CONFUCIANISM AND SCIENCE IN CHINA; CHINESE RELIGIONS, DAOISM AND SCIENCE IN CHINA; DEEP ECOLOGY; ECOFEMINISM; ECOLOGY; ECOLOGY, ETHICS OF; ECOLOGY, SCIENCE OF; ECOTHEOLOGY; GAIA HYPOTHESIS; FEMINISMS AND SCIENCE; FEMINIST COSMOLOGY; FEMINIST THEOLOGY; PROCESS THOUGHT; WOMANIST THEOLOGY

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JAY MCDANIEL

ECOLOGY, SCIENCE OF

Ecology is the study of the relationships of organisms with other organisms and with their physical environment. Ecology also includes study of the structure and functions of natural systems. The word *ecology* was first used in 1866 by the German biologist Ernst Haeckel (1834–1919), who based it on the Greek words *oikos,* meaning "household," and *logos,* meaning "study." Though modern ecology is less than a hundred years old as a science, it has quickly diversified into a number of subdisciplines, each with different concepts and research methods. Some subdisciplines can be described by organism (plant ecology, animal ecology) or by habitat (terrestrial ecology, marine ecology). Other forms of ecology reflect applied use of the science, as in restoration ecology or agroecology. In this entry, ecology will be described in terms of the scale and orientation of the scientists working on ecological questions. Common to all ecological perspectives are the role of evolution and historical change, the impacts of human activities on organisms and environments, and the use of models to represent complex interactions.

Approaches to ecology

There are six predominant approaches to ecology.

Some of the earliest work has been done by *community ecologists* who study patterns and processes in groups of species, asking questions about species diversity and complexity. A community can be defined in several ways: as the residents of a localized place, the historical presence of species in an area, a collection of co-existing populations, or as the collective interactions of species members moving through a place. Community ecology focuses on species relationships and abundance in specific places such as a desert wash, a peat bog, or a sandy beach. Typical research examines patterns of change over time such as plant succession after a fire. Scientists also study species distribution according to soil and climate conditions, and strategies used to cope with these conditions. Analytical methods include gradient analysis, diversity mapping, and computer modeling.

Population ecologists examine how and why the size of populations changes over time and place. They consider environmental factors such as temperature and rainfall as well as biological interactions such as predation. Growth rate, density, rate of reproduction, and mortality are key to understanding population flux. Population models show such things as changes in age classes over time or variability in predator-prey cycles. Factors of population regulation are important in managing game harvests and agricultural pests, as well as protecting endangered species. Population ecologists rely on field data, experimental studies, and computer modeling to chart population dynamics.

Behavioral ecologists focus on adaptive behaviors in animals that have been successful in survival and reproduction. Unlike community and population ecology, which address broad groups of organisms, behavioral ecology looks at the individual and how its behaviors have evolved to serve the individual's fitness. Life history strategies reflect the tradeoffs animals make between survival and reproduction. Drawing on field observations as well as experimental tests, behavioral ecologists use cost-benefit models and game theory to propose explanations for animal behaviors. How an animal forages for food, chooses a mate, or raises its young reveal something about the ecological contexts in which the species has evolved.

Physiological ecologists look at the biochemical constraints that define whether an organism survives or not. Variation in environmental factors such as habitat temperature, nutrient availability, and light level can be optimal or stressful, depending on an individual's tolerance. Below freezing, sensitive plant cells can burst; starved for oxygen, fish in a polluted lake can die. Thermoregulation and other mechanisms of homeostasis help stabilize organisms in response to changing abiotic conditions. To describe the dimensions of a species's ecological niche, physiological ecologists measure metabolic chemistry, energy use, and rates of growth. Radiotelemetry instruments are used to collect data on heart rate, body temperature, and environmental conditions from such animals as deep-diving whales or far-ranging wolves. In the related field of ecotoxicology, scientists track the impacts of human-made chemicals such as DDT and dioxin.

Ecosystem ecology along with landscape ecology, is one of the most recent subdisciplines to emerge in the science of ecology. The goal of ecosystem ecology is to understand the movement of energy and matter as they circulate through organisms and the environment. Studies of nutrient cycling in an ecosystem ask questions about flow patterns, seasonal variation, and biological productivity. As human activities accelerate the degradation of ecosystem functions, increasing attention has been focused on ecosystem resilience and sustainability. Many ecosystem level questions originate in the field, with information integrated into sophisticated models using statistical analyses and flow diagrams. Both restoration of damaged ecosystems and clean-up of toxic contaminants draw on the knowledge base of ecosystem ecology.

Landscape ecology examines even broader scale patterns of environmental change. Landscape-level studies focus on mosaics of habitat patches to understand causes and consequences of long-term historical change. Clearcutting or forest fires, for example, set up ecological dynamics that can change the shape of the landscape in many ways. Likewise, changes in climate or the Earth's surface through mountain-building or erosion affect species composition and habitat distribution. Aerial photographs are used to collect broad-scale information which is then stored in computerized geographic information systems (GIS). Landscape ecologists engage land management issues of patch viability and habitat connectivity, using complex maps and models to compare the impacts of different land-use policies.

Conclusion

Ecological theories have changed significantly over the last century as ecologists ask different questions and use different tools to gather and process information. From traditional natural history observation to complex modern computer modeling, ecology has made enormous advances. Ideas of nature have likewise changed and influenced the development and application of ecological theories. Earlier views of climax communities as the inevitable outcome of competition have been replaced with more dynamic views of nature. The role of human agents in ecosystem change has become more widely included in ecological analysis. While much early research was oriented to management and production goals, modern ecologists are motivated by the desire to protect and restore biological diversity and ecosystem health. As human population and consumption continue to impact the environment, the science of ecology will have a critical role to play in leading the way toward a sustainable future.

See also ANIMAL RIGHTS; DEEP ECOLOGY; ECOFEMINISM; ECOLOGY, ETHICS OF; ECOLOGY, RELIGIOUS AND PHILOSOPHICAL ASPECTS; ECOTHEOLOGY; GAIA HYPOTHESIS; FEMINISMS AND SCIENCE; FEMINIST COSMOLOGY; FEMINIST THEOLOGY; WOMANIST THEOLOGY

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ECONOMICS

The field of economics encompasses the study of how natural resources are drawn from nature and processed by human activity to become value-added products for consumption or commodities for exchange; the study of how complex services are developed by coordinating human activities so that particular services can be rationally provided, bought, or sold; and the study of how the resulting resources are allocated, and how the costs and benefits of these processes are calculated.

Highly specialized subdisciplines of this vast field developed after the Industrial Revolution, the rise to social dominance of the modern business corporation, the sharp debates between capitalist and socialist theories during the nineteenth and twentieth centuries, and the increased globalization of the contemporary world. *Econometrics* seeks to measure actual processes and their consequences in a delimited institutional range—a family, firm, nation, industry, or segment of the population such as a race or a class. *Regression analysis* seeks to develop models that can interpret the relative effects of a variable or a set of variables. Other subdisciplines focus on policy-making and are intended to bring desired social results. *Macroeconomics,* for example, focuses on tax or other governmental policies that aim to enhance development or public services, reduce poverty or inequality, or control behaviors that damage the common welfare (crime, environmental damage, drug abuse, child pornography, health or safety, etc.). *Microeconomics* seeks to enhance the efficiency, productivity, profitability, and viability of companies that operate in various markets. *Labor economics,* which often engages in advocacy, studies both political and business policies from the standpoint of their effects on employees and workers' unions. Despite their differences in focus, experts in all economic subdisciplines agree that without a sound economic infrastructure, societies falter and people suffer.

History

Economic activity has always been a part of human existence. Hunting, gathering, and cooking have taken place since humans first appeared. Production by craftsworkers to supply goods for trade and for merchants has been present in all of recorded history. Early theories of economic life date back to discussions about farmers and peddlers in the *Arthashastra,* an Indian treatise on governance from about the third century B.C.E. The concept of *shangye* (commercial occupation) in early Confucian texts sought to spell out the relationships of economic actors to political and social life. Economic theories also turn up in ancient Greek writings. Plato (c. 428–347 B.C.E.) saw the foundation of *The Republic* as rooted in economic life (Book 2), and in *Politics* Aristotle (384–322 B.C.E.) developed the idea of the "management of the household" (*oikonomia*) and applied it to the *polis.*

Moreover, economic issues were taken up by religious prophets and moral philosophers in all known cultures, and in the West the blend of biblical themes and Greek philosophy has decisively shaped the social and ethical perceptions of economic life and policy. That is so despite the fact that economics in its modern mode has sought to differentiate itself from these social, ethical, and spiritual philosophies. Indeed, it has become a truly autonomous science on the model of the natural sciences since, at least, the French physiocrats and the English post-mercantilist economists from Adam Smith (1723–1790) through the utilitarians to John Maynard Keynes (1883–1946) and the German socialists and the Austrian libertarians. It is these modern Western sets of perspectives and debates that have most shaped what is today understood as the discipline of economics.

Economics as a discipline, for all its achievements, is not identical to economic life. The heirs of Adam Smith, and those of Karl Marx (1818–1883) or Friedrich Hayek (1899–1992), have developed refined theories that describe how the "rational choices" of persons, families, classes, governments, businesses, or market mechanisms (such as a stock exchange, employment and wage rates, or a futures market) typically manifest themselves, although economists know that they are working with abstract models. The great advantage of such models is that they can be developed and applied in many concrete circumstances by ruling out idiosyncratic and extrinsic contingencies that may also influence decisions or policies but are not directly economic factors. The best economic theories not only have a mathematical and philosophical mark of elegance, they also have a high degree of reliability when applied to specific questions and adjusted to specific contexts.

These models work best in an environment that shares a common society, a common culture, and, since they deeply influence the perceptions and expectations of persons and communities, something of a common set of religious convictions. That is because the "conditionalities" of behavior, what strict economic theory considers to be idiosyncratic or extrinsic contingency, are different where divergent cultural, social, or religious convictions shape morality in distinctive ways. It is true that no one wants to be cheated and that stealing or exploitation is recognized as wrong in every culture, even if it occurs. And it is true that people seek the well-being of the persons or groups that are most important to them in all sorts of social, cultural, or religious conditions. But it is also the case that a polygamous tribal person, for example, or a Hindu caste member, a dedicated leader of an Islamic brotherhood, or a Buddhist nun will have different senses of what constitutes the well-being of persons and groups. It is, thus, not at all surprising that the banking systems in different parts of the world are operationally different, that corporations are formed in distinctive ways and led with diverse understandings of the proper role of leadership, and that workers variously evaluate their obligations to firm, family, nation, political ideology, and faith.

Basic disputes and issues

The attempts to account for these contextual differences are among the key subjects of cultural studies, the sociology of religion, and comparative religious ethics to the extent that these fields bear on economic matters; the issues are paralleled by political, legal, and aesthetic studies. In the West, John Locke (1632–1704) and Thomas Hobbes (1588–1679) can be considered exemplars of a primal disagreement about how economic life works in society. For Locke, persons have a right to their "*proprium,*" that property that they appropriate from nature by honest labor and that is necessary both for their individual existence and for the support of their family. On these bases, people form a civil society with others and construct a political society for the protection of their own and others' well-being. They are aided in this effort by the fact that all persons can, in some measure, recognize the "self-evident truths" of a universal moral law, guaranteed both by reason and by Christian scripture. If the political society does not work, or violates the moral law, the people have a right to alter it to restore their economic and social well-being.

For Hobbes, perpetual conflict over scarce resources could not be resolved by either reason or religion, and thus a sovereign had to impose a collective order by force. Politics must control economics, and no rebellion was allowed. The obvious and brutal conflicts of interests, ideologies, and religions demanded state power so that economic well-being could be obtained beyond the natural state of war. In this paradigmatic dispute, one finds not only the question of the relationship of the bee to the hive in economic life, but the issue of the relative priority of civil society to political society as determinants of economic existence.

A second set of disputes can be seen in the controversies of those who follow Georg Wilhelm Friedrich Hegel (1770–1831) and those who follow his disputatious disciple, Marx. Hegel held that spiritual or mental (*geistliche*) realities fundamentally shape material realities in a decisive dialectic. Marx, famously turning Hegel on his head, argued that it was not "superstructural" factors that shaped "substructural" factors, but rather the material realities of life that determined human consciousness. Any correlation between religious orientation and economic life was an effect of economic forces that evoked the religious sighs of the people, while those who had control of the means of production perpetuated these dreams to control the workers.

These theories combine in mixed ways. A version of the materialist view can be found among various contemporary disciples of Charles Darwin (1809–1882). Some of them, including the Nobel Prize winning economist Gary Becker (1930–), hold to an "evolutionary psychology" in which individuals make "rational choices" about not only business matters but also about whom to marry and whether to have children on the basis of their calculation of material interests. A collectivist view of economic behavior is set forth by Edward O. Wilson (1929–) in his sociobiological theories; this view sees religion as an illusory cultural by-product of collective material and instinctual dynamics.

More influential in the understanding of the relationship of religion and economic life is the work of Max Weber (1864–1920). His five volumes on the *Sociology of Religion* and his three volumes on *Economy and Society,* written early in the twentieth century, argued that different religions have distinct effects on economic (and political) life and on various classes and occupational groups in society. Weber saw not only that the late medieval Roman Catholic faith had an economically positive influence in the emerging free cities of northern Europe in the very early stages of modernity, but that the Protestant ethic gave impetus to the formation of what is now known as the break with traditional, feudal economies and the development of modern capitalist industries. Weber's arguments were doubted during the harsh realities of the Great Depression (which saw greater use of Marxist theory and the rise of Fascism), and were often ignored after World War II when Keynes's economic theories came to ascendancy, but Weber's work regained attention after the collapse of the Soviet Union in the early 1990s and the resurgence of religion all over the world. Today, few economists think that Weber's treatments of India and China were fully adequate, and questions about aspects of his views of Catholicism, Protestantism, and Islam are manifold. Yet, it is widely held that the questions he raised and the methods of investigation he developed are among the most definitive for the ongoing discussions between religion and economic life.

In a postmodern age, the predicted certainties of inevitable secularization that seemed beyond dispute, of a purely scientific view of reality that could provide firm foundations for progressive public policy, clear-minded corporate decision-making and personal rational choices without illusion, and the end of both ideology and religious myth seem positively silly. Indeed, it turns out that a deep convergence of inter-contextual reasonability and moral conviction, not equally available in all religions, are critical for the economic well-being of persons and peoples. The body of contemporary literature that points in this direction is found in a host of Weber-influenced studies that document the interactions of religion and economic life, and point out that the basic assumptions behind contemporary secular economic theory are, in fact, echoes of religious convictions that are well, but not fully, masked.

See also CULTURE, ORIGINS OF; MATERIALISM; MORALITY

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ECOTHEOLOGY

The term *ecotheology* came into prominence in the late twentieth century, mainly in Christian circles, in association with the emergent scientific field of ecology. Ecotheology describes theological discourse that highlights the whole "household" of God's creation, especially the world of nature, as an interrelated system (*eco* is from the Greek word for household, *oikos*). Ecotheology arose in response to the widespread acknowledgment that an environmental crisis of immense proportions was threatening the future of human life on the earth. Ecotheology also arose in response to what has been called "the ecological complaint" against Christianity.

The ecological complaint

Some scholars and critics maintain that the Christian faith helped set the stage for the global environmental crisis by instructing generations of believers that God transcends nature, that humans likewise transcend nature, and that nature therefore has meaning in the Christian schema only as an instrument for God's purposes with humans. The signature Christian teaching in this respect was the theology of human dominion over nature (also called *stewardship*), a theology that encouraged manipulation, even exploitation, of nature for the sake of human purposes. According to these scholars and critics, Christianity is unavoidably anthropocentric, no longer relevant to the ecological world, and even, in a sense, spiritually dangerous.

The historical truth, however, is more complex, as a review of Christian theology since 1500 will show. While the emergence of ecotheology is relatively recent, its historic roots in the Christian theology of nature are deep. Christians have held a variety of views about nature, all of them rooted in widely divergent socioeconomic and cultural situations. A nuanced understanding of Christian attitudes to nature must address those differing contexts as well as the explicit theological teachings themselves.

A critical case is the Christian understanding of human dominion over nature. The meanings of this teaching varied substantially from one period to another. From about 1500 to 1750, human dominion was understood in terms of survival in the midst of a threatening world. Much economic life in those times was carried on at a subsistence level, highly dependent on the precarious cycles of small-scale agriculture. Except for the most wealthy, the vast majority of the people had to struggle, with minimal aid from technology and with pervasive dependence on farm animals, such as oxen, in order to hack out agricultural spaces from the primeval forests, where threatening predators, such as wolves, roamed freely, and where a sustainable level of agricultural productivity was highly uncertain. Moreover, although many people lived in the same buildings with their farm animals, which were part of their domestic world, their attitudes toward wild animals tended to be negative, especially within the ranks of the wealthy, who sometimes fostered a hunting culture predicated on delight in killing.

In this socioeconomic context, the biblical idea of human dominion over the earth would have been read and enacted in terms of a life-and-death struggle with the vicissitudes of nature. After the mid eighteenth century, towns and cities emerged in significant numbers in Europe, and human dominion over nature was no longer interpreted in the context of an agricultural struggle for survival, but more in terms of an increasingly crowded urbanized world that was predicated on the exploitation of nature, a world that sometimes prompted a romantic nostalgia for the remembered beauties and purities of life in the country. Human dominion over nature came to be viewed by some believers as a problem, rather than as a self-evident mandate in the quest for survival.

By the beginning of the twentieth century, trends of massive urbanization and industrialization, constantly expanding applications of earth-shaking technologies, especially in mining and agriculture, and concomitant pollution of the land, sea, and air in virtually every region of the planet had increased to the breaking point. Issues of human survival on the earth began to emerge, heightened by a growing awareness of the related problems of global poverty, exhaustion of nonrenewable natural resources, and enormous population growth. This global crisis, in turn, posed unprecedented questions to Christian communities around the world. The Christian teaching of human dominion over the earth came under attack, both by believers and by critics hostile to the Christian tradition, because it seemed to symbolize much that was wrong with the way humans had chosen to live on the earth. By the end of the twentieth century, the theme of human dominion over nature had become, in the eyes of many, a scandal. On the other hand, the same theme continued to be affirmed by a few leading Christian theologians and by numerous prominent Christian public policy-makers, who wrote and acted as if the world needed nothing more than business-as-usual.

Such were the major socioeconomic contexts to which Christian theologians responded, consciously or unconsciously. Significantly, these trends were made possible by the burgeoning natural sciences, above all by the mechanistic science championed by Isaac Newton at the turn of the eighteenth century and by the evolutionary science advocated by Charles Darwin during the nineteenth century. Theology was buffeted by these cultural forces, too, especially by Darwinism, which sent tidal waves of anti-religious sentiment coursing through the intellectual world of the times. On the other hand, many theologians thought of their work not as responding to questions raised by socioeconomic or cultural trends, but as a creative exposition of the whole body of traditional Christian teachings, according to the tradition's own norms.

The world of nature and Protestantism

Self-conscious theological reflection about the world of nature was most prominently launched by the two major Protestant reformers of the sixteenth century—Martin Luther and John Calvin—who gave voice to a rich theology of nature. "In every part of the world, in heaven and on earth," Calvin wrote in his *Institutes,* God "has written and as it were engraven the glory of his power, goodness, wisdom and eternity . . . For the little singing birds sang of God, the animals acclaimed him, the elements feared and the mountains resounded with him, the river and springs threw glances toward him, the grasses and the flowers smiled." Calvin even suggested that when humans contemplate the wonders of God in nature "we should not merely run them over cursorily, and, so to speak, with the fleeting glance, but we should ponder them at length, turn them over in our mind seriously and faithfully, and recollect them repeatedly."

Luther had a similar view of the glories of God in the whole creation and of creation's marvels. "If you truly understood a grain of wheat," he once wrote, "you would die of wonder." In his commentary on Genesis, Luther imagined Adam and Eve before the fall enjoying a common table with the animals. In the same spirit, both reformers thought theocentrically about human interactions with nature: God and his righteousness will set very real limits for the reaches of human pride and arrogance. The created world belonged first and foremost to the Creator and humans were mandated by God to exercise dominion over the earth. But that dominion was understood to be a restoration of Adam's and Eve's lives as caretakers or gardeners, not as a license for exploitation.

Further, both Calvin and Luther affirmed the immediacy of God in nature. For them, God was not detached from the world, far above in some spiritualized heaven. On the contrary, as Luther often said, God is "in, with, and under" the whole created world. This view of nature as divinely given and divinely charged came to its completion in their the reformers' teachings about "last things" (eschatology). Both theologians strongly emphasized the traditional Christian teaching about the resurrection of the body. Both also projected a view of the end of the world as a cosmic consummation, the coming of the "new heavens and new earth" announced in biblical traditions. Nature itself would be "saved" and consummated at the very end.

Fatefully, however, the issues that preoccupied Luther and Calvin had to do not with God and nature, but with God and human salvation. Their theologies, accordingly, took on an anthropocentric character. "Justification by grace through faith alone" was the theological teaching that most occupied their attention. Furthermore, Calvin accented the responsibility of Christians to change the world for the better, teaching that the world was the arena for righteous work and faith-driven social transformation.

The theological heirs of Luther and Calvin, especially in the nineteenth century and thereafter, took the reformers' measured anthropocentrism as a given, but tended to leave behind the reformers' rich teaching about God and the natural world. As a result, Christian theology became more exclusively anthropocentric. There were many reasons for this marked shift of emphasis, not the least of them being the rise of Newtonian mechanistic science and Darwinian evolutionary science, and the need by these post-Reformation theologians to root religious faith in the intangible human spirit or human subjectivity, so as to leave the objective world of nature to natural scientists, and also to protect faith from the attacks of some scientists and scientifically informed philosophers. This anthropocentric dynamic also made it easy for both theologians and Christian lay people to be swept along by the dynamics of industrial society, which were predicated on the exploitations of the earth for the sake of human progress.

Accordingly, many theologians in the first half of the twentieth century, like Emil Brunner and Karl Barth, self-consciously refused to project theologies of nature. Their theologies focused on God and humankind alone. When they did talk about nature, it was typically in highly anthropocentric terms. Both Brunner and Barth affirmed, for example, that the purpose for which God created the world was to have a redemptive history with humankind. Brunner called nature merely "the scenery" for the divine-human drama.

Catholic theologians had to deal with the same socioeconomic and cultural trends, but the officially sanctioned teachings of the Catholic Church tended to be mainly reactive to the expanding claims of the natural sciences, until well into the twentieth century. Traditional Catholic teachings about God's creation of the world and human dominion over the earth were simply affirmed against the advances in science represented by Newton and Darwin. Thus the work of twentieth–century Catholic paleontologist and theologian Pierre Teilhard de Chardin, who claimed evolution as a theological theme, were banned by the Papacy until the middle of the twentieth century.

The ecological turn

It was not until the second half of the twentieth century that Christian theology began to take an ecological turn. Teilhard himself had led the way by incorporating evolutionary thought into the corpus of his theology, although Teilhard's theology remained anthropocentric in many ways. The mid-century Protestant thinker Paul Tillich was also a prophetic voice, eschewing the anthropocentrism of theologians like Brunner and Barth, radically criticizing the destructive power of modern "technical reason," and richly reaffirming and reinterpreting Luther's theology of nature in terms of Tillich's own doctrine of God as "the Ground of Being." The era of ecotheology fully emerged, however, only in the 1960s. It was first announced publicly by the pioneering Protestant ecotheologian Joseph Sittler. Drawing on Paul's Letter to the Colossians, Sittler called for a new theology of grace that included rather than excluded nature. Sittler was the first to give the term *ecology* public prominence as a theological construct and also took the lead in establishing conversations with ecologists like Aldo Leopold and reconsidering Christian poets of ecological consciousness such as Gerard Manly Hopkins.

Perhaps the single most important advocate of ecotheology toward the end of the twentieth century was the ecumenically oriented Protestant theologian Jürgen Moltmann. Drawing on the theologies of the reformers, the fruits of twentieth century studies of biblical eschatology, and immanentalist insights from the traditions of Jewish mysticism, Moltmann projected a theology of hope for the whole cosmos, giving a holistic, ecological shape to Christian teaching, including an impressive response to issues of global poverty, so much a part of the emergent global environmental crisis. The Protestant theologian John Cobb also made substantial contributions to Christian thought about nature, especially by his explorations of the resources offered to ecotheology by process thought, associated with the work of the twentieth century philosopher Alfred North Whitehead.

Ecotheological ethics emerged, too, as a theological field in its own right through the labors of scholars like the Protestant theologian James Nash, who argued that "loving nature" must be an essential theme for Christian theology. Catholic thinkers, such as Thomas Berry and Denis Edwards, made significant contributions to ecotheology drawing respectively on the findings of twentieth-century scientific cosmology and on the wisdom theology of the Bible. In addition, a number of Christian ecofeminists, most prominent among them Rosemary Radford Ruether and Sallie McFague, offered a range of fresh theological methodologies and insights, often reading between the lines of traditional texts to discern how the experience of women and the theological appreciation of nature had been suppressed by normative patriarchal theologians. In addition, the testimony of Eastern Orthodox theology, voiced by thinkers such as Paulos Gregorios, was heard in ecumenical circles emerging from centuries of affirmation of nature by many Orthodox communities. Toward the end of the twentieth century, a growing number of biblical scholars moved away from the anthropocentric assumptions of the previous generation to new and often highly suggestive understandings of the biblical theology of creation.

Vision of ecotheology

All these thinkers presented visions of nature much more consonant with the theologies of Luther and Calvin—although often departing from the reformers' thought in significant ways—than with later anthropocentric trajectories of Christian thought. Viewed as a theological movement, these late twentieth-century ecotheologians can be said to have shared a single vision, rooted in early modern theologies of nature. Characteristically, they championed:

(1) the idea of divine immanence in the whole cosmos;

(2) a relational, ecological rather than a hierarchical understanding of God, humans, and the created world;

(3) a radically reinterpreted view of human dominion over nature in terms of partnership with nature; and

(4) a commitment to justice for all creatures, not just humans, highlighting the needs of the impoverished masses and endangered species around the globe.

Their theological labors, along with the work of numerous other theologians, reflected theological concerns that emerged from the grass roots in churches around the world. These concerns came to public expression in the second half of the twentieth century in the form of a number of prophetic teachings promulgated by denominational and ecumenical bodies in order to address the global environment crisis. By the year 2002, Christian ecotheology had emerged as a theological movement that had begun to speak with a new and powerful voice on behalf of the whole creation "groaning in travail" (Rom. 8:22).

See also ANIMAL RIGHTS; ANTHROPOCENTRISM; DEEP ECOLOGY; ECOFEMINISM; ECOLOGY; ECOLOGY, ETHICS OF; ECOLOGY, RELIGIOUS AND PHILOSOPHICAL ASPECTS; ECOLOGY, SCIENCE OF; GAIA HYPOTHESIS; FEMINISMS AND SCIENCE; FEMINIST COSMOLOGY; FEMINIST THEOLOGY; PROCESS THOUGHT; WHITEHEAD, ALFRED NORTH; WOMANIST THEOLOGY

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H. PAUL SANTMIRE

EINSTEIN, ALBERT

Albert Einstein is generally regarded as the greatest theoretical physicist of the twentieth century, if not of all time. Modern physics bears his mark more than any other physicist. His Special Theory of Relativity changed our conceptions of space, time, motion, and matter, and his General Theory of Relativity was the first new theory of gravitation since Isaac Newton's. Yet his work went beyond the boundaries of physics as he engaged himself in the educational, cultural, and philosophical concerns of his generation. Less known is Einstein's interest and personal engagement in religious matters. In specific, he strongly opposed the proposition that science and religion are irreconcilable.

Early life and influences

Albert Einstein, whose ancestors had lived in southern Germany for many generations, was born on March 14, 1879, in Ulm, Germany. The fact that his parents, Hermann Einstein and Pauline Einstein, née Koch, did not call him Abraham after his deceased grandfather, as Jewish tradition required, and that his sister, his only sibling, born 1881, was called Maria, shows that his parents did not observe religious rites although they never renounced their Jewish heritage. In 1889, the Einstein family moved to Munich, where Albert at the age of six was sent to a Catholic elementary school. At home a distant relative introduced him to the principles of Judaism and evoked in him such a fervent religious sentiment, that he observed Jewish religious prescriptions and even chided his parents for eating pork. At age ten he entered the interdenominational Luitpold Gymnasium, where he excelled in mathematics and Latin.

Ironically, his religious enthusiasm ended abruptly as the result of the only religious custom his parents observed, the hosting of a poor Jewish student for a weekly meal. This beneficiary was Max Talmud, a medical student older than Albert by ten years. He gave Albert books on science and philosophy, amongst them Ludwig Büchner's (1824–1899) materialistic *Force and Matter* (1874). Albert was particularly impressed by Büchner's survey of theriomorphic and therianthropic religions, in which animals or their combinations with humans were apotheosized. As Einstein, in his autobiographical notes, wrote, "through the reading of these books I reached the conclusion that much in the stories of the Bible could not be true. The consequence was a fanatic freethinking . . . suspension against every kind of authority . . . an attitude which has never again left me, even though later on, because of a better insight into the causal connections, it lost much of its original poignancy" (Schlipp p. 5).

In 1894, Albert's parents, for commercial reasons, moved to Italy. Left alone and hating the authoritarian discipline at the Gymnasium, Albert joined his parents before finishing school. At the Swiss cantonal school in Aarau he obtained the diploma that enabled him to enroll in the Swiss Federal Polytechnic School (ETH) in Zurich, where he studied physics and mathematics and graduated in 1900. Unable to find a regular academic position, he supported himself by tutoring and part-time school teaching until June 1902, when he obtained the appointment of technical expert third class at the patent office in Berne. A year later he married Mileva Maric, a Greek Orthodox Serbian, with whom he had fallen in love when they were classmates at the ETH. Little is known about their daughter Lieserl, who was born in 1902 before their marriage during Mileva's visit to her parents. Albert seems never to have seen her. Their first son, Hans Albert, was born in 1904, and their second son, Eduard, in 1910.

Theories and career

Einstein liked the job at the patent office because it was interesting and also left him time to pursue his own work in theoretical physics. He already had a number of important publications, mostly on thermodynamics, to his credit. But the year 1905 became his *annus mirabilis*. In March he completed his paper on the light-quantum hypothesis, in May his paper on Brownian motion, and in June his celebrated essay on the special theory of relativity, which was followed in September by his derivation of the famous mass-energy relation $E = mc^2$, the most famous equation in science.

In 1908 Einstein became Lecturer at the University of Berne, in 1911 full professor in Prague, and a year later he became a professor at the ETH. In April 1914, less than four months before the outbreak of the First World War, he moved to Berlin with his wife and two sons to serve as university professor without teaching obligations and as director of the Kaiser Wilhelm Institute of Physics.

Mileva disliked Berlin and returned with the children to Zurich. In February 1919 Albert and Mileva got divorced. Six months later Einstein married his cousin, the divorced Elsa Löwenthal, mother of two daughters, Ilse and Margot. Einstein detested the military enthusiasm that swept Germany after the declaration of war and courageously refused to sign the manifesto, in which German intellectuals declared their solidarity with German militarism.

Einstein continued his work on the general theory of relativity, which he had begun in 1907. In November 1915, he derived the exact value of the perihelion precession of the planet Mercury, which for over sixty years had been an unresolved problem, and he predicted how much a ray of light, emitted by a star and grazing the sun, should be deflected by the gravitation of the sun. In 1917 he applied general relativity to the study of the structure of the universe as a whole, raising thereby the status of cosmology, which theretofore had been a jumble of speculations, to that of a respectable scientific discipline. His prediction of the gravitational deflection of light was confirmed in 1919 by two British eclipse expeditions to West Africa and Brazil. When their results were announced in London, Einstein's theory was hailed by the President of the Royal Society as "perhaps the greatest achievement in the history of human thought." From that day on Einstein gained unprecedented international fame. In 1922, he was awarded the Nobel Prize for physics. But when the Nazi terror began in Germany, he, as a Jew and pacifist, and his theory, became the target of brute attacks. At Adolf Hitler's rise to power early in 1933, Einstein was in Belgium and, instead of returning to Germany, accepted a professorship at the Institute for Advanced Study in Princeton, New Jersey, where he remained until his death on April 18, 1955.

Later life and influence

During the twenty-two years in Princeton he resumed his work on quantum theory. Although he was one of its founding fathers, he rejected its generally accepted probabilistic interpretation because, influenced by the philosopher Baruch Spinoza (1632–1677), whom he had read in his youth, he was utterly convinced of the causal dependence of all phenomena. Nor did he accept the prevailing view that the concept of a physical phenomenon includes irrevocably the specifics of the experimental conditions of its observation. For him "physics is an attempt conceptually to grasp reality as it is thought independently of its being observed" (Schlipp, p. 81). His famous 1935 paper, written in collaboration with physicists Nathan Rosen and Boris Podolsky challenged the completeness of orthodox quantum mechanics and had far-reaching consequences debated still today. But most of his time, until the day of his death, he devoted to the last great project of his life, the search for a unified field theory, which however remained unfinished.

Apart from his scientific work Einstein, using his prestige, engaged himself in promoting the causes of social justice, civil liberty, tolerance, and equity of all citizens before the law. He believed in the ideal of international peace and in the feasibility of establishing a world government, led by the superpowers, to which all nations should commit all their military resources. Although having signed in August 1939 the famous letter to President Franklin Delano Roosevelt proposing the development of an atomic bomb, he later admitted that, had he known that the Germans would not succeed in producing an atomic bomb, he "would not have lifted a finger."

Having been, during his later years in Berlin, a victim of anti-Semitic propaganda, and being aware of the cruel persecutions of Jews by the Nazis, Einstein most actively supported Zionism, which he regarded as a moral, not a political, movement to restore his people's dignity necessary to survive in a hostile world. When once, in this context, he declared: "I am glad to belong to the Jewish people, although I do not regard it as 'chosen'" (Schlipp, p. 81) he obviously referred to his disbelief in the Bible, which he retained from his adolescence. And when he said, as quoted above, that he later recanted his juvenile freethinking "because of a better insight into causal connections," he referred to his realization that science, by revealing a divine harmony in the universe expressed by the laws of nature, imbued him with a feeling of awe and humility that made him believe in a "God who reveals himself in the harmony of all that exists." He defined the relation between science and religion in a much-quoted phrase: "Science without religion is lame, religion without science is blind." But retaining his early uncompromising rejection of anthropomorphisms, he stated that, following Spinoza, he cannot conceive of a God who rewards or punishes his creatures or has a will of the kind humans experience. In his Princeton years, Einstein wrote numerous articles and addresses on what he called his "cosmic religion" and protested strongly against the identification of his belief in an impersonal God with atheism. The philosophy of religion and the quest for religious truth had occupied his mind in those years so much that it has been said "one might suspect he was disguised as a theologian," as the Swiss playwright Friedrich Dürrenmatt once said.

On December 31, 1999, the well-known weekly newsmagazine *Time* proclaimed Albert Einstein "Person of the Century" on the grounds that he was not only the century's greatest scientist, who altered forever our views on matter, time, space, and motion, but also a humanitarian, who fought for the causes of justice and peace, and "had faith in the beauty of God's handiwork."

See also GRAND UNIFIED THEORY; GRAVITATION; PHYSICS, QUANTUM; RELATIVITY, GENERAL THEORY OF; RELATIVITY, SPECIAL THEORY OF; SPACE AND TIME

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MAX JAMMER

EMBODIMENT

What concept of *embodiment*—of the bodily becoming of life itself and of any life-form—emerges in the interstices of religion and science? All religions minister to the vulnerabilities and passions of the body, lending meaning to mortality through practices of ritual, discipline, and narrative. Such interpretive practices nestle the human body into its cosmic environment of fellow creatures, even as they distinguish it in its humanity. The biblical creation narratives, for example, stress the goodness of all species in their interdependence. Christianity offered a dramatic symbolization of God-becoming-flesh, heightening the importance of the body, whose resurrection as part of the "Body of Christ" defined salvation itself. Presumably this radicalization of embodiment, against the background of the unqualified goodness of nature itself, helps to explain why it is on Christian soil that natural science in its full modern sense arose. Yet paradoxically the same Christian paradigm effected some of humanity's most dualistic discourses, inhibiting full-bodied appreciation of the material world and perhaps explaining why the rise of science took the form of a polarizing struggle. It may also conversely shed light upon why Christianity has failed to inhibit the more devastating effects of scientific technology upon the planetary ecology.

This paradox, pulsing with ambivalence toward the body, lies at the heart of Western history. As the early Christian movement first struggled to translate its gospel into the terms of Greco-Roman culture (for which science and philosophy were inseparable), there was no greater stumbling block than "the body." The body, in its ceaseless metamorphosis from birth to death, signified for classical thought the realm of change. By the same logic, God would be incapable of change. Thus it is the source of truth, of the unchanging ideas—or forms—that organize the changing world of nature (*physis*). The categorical distinction between the eternal "One" and the mortal "Many" accounts for the compatibility between philosophical Hellenism and the Jewish monotheism of the Christians. But the Greek dichotomy between changeless "Being" and the changing world of bodies, between Aristotle's (384–322 B.C.E.) unmoved "Mover" and the moving world, did not fit the Christian proclamation of an incarnation of the divine. The orthodox Christian solution finally made it fit: In the form of the "two natures" of Christ, the divine Word inhabited the human body, but remained in itself free of change, feeling, or flesh. The paradox was institutionalized.

It took nearly a thousand years for Christianity to develop genuine interest in the mortal human body. A seemingly subtle shift in the classical sources effected a dramatic change: Appropriated from Muslim scholars during the crusades, Aristotle's texts—and a different, scientific reading of Aristotle—came to the fore of Christian thought. Unlike Plato (428–347 B.C.E.) , true knowledge, according to Aristotle, can only arise out of sense experience. Such embodied experience requires the illumination of reason and then, in its Christian reception, the completion by faith. Although the fundamental Greek ontological binary of unchanging reason and bodily phenomena remained intact, the epistemology changed radically. In the new Western universities of the thirteenth century, that shift gave rise to a certain autonomy of the discipline of "philosophy" (which included what is meant today by the sciences) from theology. The Dominican Albertus Magnus (c. 1193–1280) and his pupil Thomas Aquinas (c. 1225–1274) developed systematically the implications of this new interest in the integrity of the embodied senses and the world of bodies. Aquinas read the human rational soul as the form, or actualization, of its own body. The body is the potentiality, enmeshed in a prima matter or pure potentiality comprised of contiguous bodies of varying densities.

The Platonic dualism however soon reconquered theology on the whole. When in the Renaissance a more favorable attitude toward the body became again apparent, it took a Platonic form, propelled largely by the idealized body-forms of art. Within the milieu of a Renaissance neo-Platonic mysticism, driven by a powerful mathematics in which the multiple infinities of the embodied universe were articulated, Cardinal Nicholas da Cusa (d. 1464) and his martyred disciple Giordano Bruno (1548–1600) initiated a fresh, proto-scientific theological discourse, in which God and world fold in and out of each other. The Protestant Reformation, by contrast, reacted against the paganism of these new arts, as well as against the sensuality of the sacramental system. It was, to twist the above paradox further, the extreme form of Platonic dualism of René Descartes (1596–1650), boiled down to "mental substance" and "extended substance," that provided the initial framework for modern science. The mechanistic rather than the mystical approach to the spirit/world, mind/body relation prevailed in science and theology, even as the gap widened between the disciplines. The body as a machine, as a closed system to which spirit, mind, and God, if they exist, were posited as external agents, dominated the western imagination until the twentieth century.

The dynamic unfolding of the organism through chance in evolution, the relativity of the physical universe, and the indeterminacy of the quanta begin to reopen the system. The mathematician and cosmologist Alfred North Whitehead (1861–1947) first conceptualized the philosophical and theological potentialities of this shake-up of the old modern reductionisms. His conversion of something like the Aristotelian passive prime matter into the activity of a primal "Creativity," from which God and world unfurl freely and in immanent relation, has had tremendous influence on the formation of the field of religion and science. Process theology can thus present God as embodied—not as a sum of bodies à la pantheism, but as the spirit of the universe, partly and differently incarnate in all creatures. This panentheism thus redistributes the incarnation throughout reality: All actualization is embodiment, including the divine self-actualization in the world; the unique incarnation of God in the symbolism of the Christ no longer represents an exception that proves the rule of spirit/body dualism. Feminist and ecological theologies have been evolving in close proximity to this sense of inclusive embodiment, emphasizing the implications for social and environmental justice of a new profoundly spiritual attention to interdependent, vulnerable human bodies, within their systemic contexts of socio-material interchange.

New developments in genetics, for example, offer stunning contributions to the human sense of embodiment. The recipe that links heredity to the metabolism of human life is "a code, an abstract message that can be embodied in a chemical, physical or even immaterial form" (Ridley, p. 15). The secret of this code lies in its ability to replicate itself in the form of proteins: and so to produce bodies from an ancient alphabet of infinitesimal filaments. "In the beginning was the word," avers a science writer with no specific interest in religion. "The word proselytized the sea with its message, copying itself unceasingly and forever. The word discovered how to rearrange chemicals so as to capture little eddies in the stream of entropy and make them live. The word transformed the land surface of the planet from a dusty hell to a verdant paradise. The word eventually blossomed and became sufficiently ingenious to build a porridgy contraption called a human brain that could discover and be aware of the word itself" (Ridley, p. 11). This gospel of genetics may be put to reductionist or commercial use. But it articulates awe in the face of the alphabetic code of the four bases (*A*, *C*, *G*, and *T*) that in its four million year simplicity writes the recipes for the endless complexity emerging with startling order out of the chaotic potential of the world. Nowhere has the interconnectivity and common source of all living creatures been more clearly demonstrated as in this emergent genetics, outside of religious narratives of genesis.

As science begins to outgrow its modern model of bodies as closed systems, as increasingly bodies are inscribed in cosmological and ecological contexts of such irreducible complexity as to solicit awe rather than certainty, religion may find the resources for healing the split between its words of spirit and its bodies of shared flesh.

See also ARISTOTLE; CHRISTOLOGY; DESCARTES, RENÉ; ECOTHEOLOGY; FEMINIST THEOLOGY; GENETICS; GOD; HUMAN NATURE, PHYSICAL ASPECTS; HUMAN NATURE, RELIGIOUS AND PHILOSOPHICAL ASPECTS; INCARNATION; ISLAM; PANENTHEISM; PHYSICS, QUANTUM; PLATO; SOUL; THOMAS AQUINAS; WHITEHEAD, ALFRED NORTH

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CATHERINE KELLER

EMERGENCE

The term *emergence* refers to the appearance of a new property in an evolving system or entity. As the system changes over time, a new property that was not present before comes to be associated with it, often through an increase in complexity. Emergent phenomena are not fully reducible (in a causal, explanatory, or ontological sense) to the lower-level phenomena from which they arise. Emergence thus represents the hypothesis that the whole story (in science, and perhaps in religion) can only be told by multiple causal stories at multiple levels.

In the religion-science discussion, uses of the term *emergence* fall roughly into three broad categories: (1) *Scientific emergence* concentrates on individual instances and patterns of emergence in the natural world. Many emergent phenomena can be categorized and analyzed in a purely scientific manner without needing to raise broader questions about their philosophical or theological significance. (2) *Philosophical emergence theories* look for broader patterns or similarities between emergent phenomena and attempt to formulate general criteria for classifying a phenomenon as emergent. (3) *Metaphysical* or *theological emergence theories* presuppose that the natural world is hierarchically structured and that it is a fundamental feature of reality that new emergent levels are produced in the course of cosmic history. At the metaphysical level, emergence theories attempt to describe and account for the broad pattern of emergence over time. In theological theories, the ladder of emergence is associated with the nature and action of God. Both presuppose the fundamental nature of change or development and emphasize creativity or novelty as a basic feature of ultimate reality.

Critics of emergence complain that it is either trivial, untestable, or false. *Trivial* because it seems obvious that, as systems increase in complexity, they will express new properties not manifest at earlier stages. Thus the critic might complain that emergence just restates the concept of complexity—and in a less clear, more obscure fashion. *Untestable* because how could one ever test whether there is a broad pattern of emergence in natural history? And *false* if emergentists are claiming that mysterious new things emerge in cosmic history that cannot be understood at all in terms of more basic levels. After all, critics complain, the success that physics has enjoyed is simply success at explaining "new things" in terms of more fundamental laws.

Some classical theists have criticized emergence theories by responding that the basic nature of the world was set by the last day of creation. Humanity may move toward or away from God, but human nature as such does not change—and certainly God does not change or emerge over time, as both Augustine of Hippo (354–430) and Thomas Aquinas (c. 1225–1274) maintained. Process thinkers have argued that emergence is not as metaphysically satisfactory as, for example, Alfred North Whitehead's (1861–1947) thought, since in place of the unified framework of actual occasions (panexperientialism), emergence offers only a confusing variety of fundamental entities arising within natural history.

Instances of emergence in the natural world

The first cases of emergence arise already in quantum mechanics. (Indeed, one could speculate that spontaneous symmetry breaking constitutes the earliest instance of emergence.) In the fractional quantum Hall effect, electrons act together in strong magnetic fields to form new types of "particles." Likewise, atomic structures and the properties of bulk matter are the emergent and relatively stable results of increasing complexity in physical systems.

Thermodynamics is inherently concerned with emergence, since it relates exchanges of heat to macroscopic phenomena such as temperature, pressure, and volume. Ilya Prigogine studied the thermodynamics of irreversible processes, developing laws for the emergence of order (anentropy) in specified systems ("order through fluctuations"). To take an example from fluid turbulence, heating a fluid from below results in the Bénard phenomenon, in which the convecting fluid spontaneously forms complex hexagonal "cells." Using similar physical principles, meteorologists study emergent patterns in the weather, which demonstrate very sensitive dependence on small changes in initial conditions (e.g., Edward Lorenz's Butterfly Effect). In such systems "matter displays its potential to be self-organizing and thereby to bring into existence new forms . . . under the constraints and with the potentialities afforded by their being incorporated into systems the properties of which, as a whole, now have to be taken into account" (Peacocke, 1986, p. 53).

The emergence of life depends on emergent properties in chemistry, such as the folding properties of proteins, which in turn are products of their underlying physical structure. Likewise, autocatalytic (self-catalyzed) processes in chemistry play a key role in increasing complexity to the level required for life. Such processes allow for the role of feedback mechanisms, which can foster an iterative, self-correcting process that leads to the formation of new structures.

Eventually, ordered dissipative structures emerged. Life requires only that they have the potential to replicate and to incorporate environment-induced changes into their physical structure. At this point biological evolution begins, in which differential survival rates depend on reproductive success in a given environment. Emergence connotes both the unbroken chain of development backward through time and the continual emergence of new forms: bio-molecules, cells (including neurons), organelles, organs, and "autonomous agents," which Stuart Kauffman defines as systems that are able to reproduce and also able to carry out at least one thermodynamic work cycle.

Emergence may involve the evolution of new structures according to as many as six metrics:

(1) evolution temporally or spatially;
(2) evolution in the progression from simple to complex;
(3) evolution in levels of inner organization, feedback loops, and self-catalyzing autopoiesis (Niels Gregersen);
(4) evolution in increasing levels of information-processing;
(5) evolution in the development of "subjectivity" (e.g., perception, awareness, self-awareness, self-consciousness, spiritual intuition);
(6) evolution in the ladder of emergence of new properties (e.g., physiological, psychological, sociological; or physical, biological, psychological, spiritual).

Philosophical analysis and implications

Understood as a philosophical position, emergence theory is derived from the details of cosmic evolution as revealed through the various natural and social sciences. Philosophical emergence generally includes some combination of the following eight theses:

(1) *Emergentist monism*: There is one natural world composed of matter and energy (Peacocke and Clayton in Russell, 2000).
(2) *Hierarchy*: This world is hierarchically structured; more complex units are formed out of more simple parts, and they in turn become the "parts" out of which yet more complex entities are formed.
(3) *Temporal ontology*: This process of hierarchical structuring takes place over time; cosmic evolution moves from the simple to the

more complex, and new structures and entities emerge in the process.

(4) *Emergentist pluralism*: The manner of the emergence of one level from another, the qualities of the emergent level, the degree to which the "lower" controls the "higher," and many other features vary depending on which instance of emergence is being studied (e.g., the biophysicist Harold Morowitz has identified at least twenty-eight different levels). Emergence should thus be viewed as a family resemblance term.

(5) *Logical features*: The various instances of emergence in natural history do tend to share certain features. For any two levels, L_1 and L_2, where L_2 emerges from L_1, (a) L_1 is prior in natural history; (b) L_2 depends on L_1, such that if the states in L_1 did not exist, the qualities in L_2 would not exist; (c) L_2 is the result of a sufficient degree of complexity in L_1; (d) one might be able to predict the emergence of some new or emergent qualities on the basis of what one knew about L_1. But one would not be able to predict the precise nature of these qualities, the rules that govern their interaction (or their phenomenological patterns), or the sorts of emergent levels that they may in due course give rise to; (e) L_2 is not reducible to L_1 in any of the standard senses of "reduction" in the philosophy of science literature (causal, explanatory, metaphysical, or ontological reduction).

(6) *Downward causation*: In some cases, phenomena at L_2 exercise a causal effect on L_1, which is not reducible to an L_1 causal history. This causal nonreducibility is not just epistemic, in the sense that humans cannot tell the L_1 causal story but an omnipotent being could. It is ontological: The world is such that it produces systems whose emergent properties exercise their own distinct causal forces among each other and on (at least) the next lower level in the hierarchy.

(7) *Against dualism*: Although the emergence of consciousness in the brain is significant to humans, it is not the defining moment of emergence. Emergence theory refers to the process of emergence as a whole, not merely to a single instance of emergence.

(8) *Against dual aspect monism*: Traditionally, as in Baruch Spinoza (1632–1677), dual aspect monism implies that there is no causal interaction between mental and physical properties, whereas emergence theories maintain that there is a dependence of the mental upon the physical and two-way causal influence between them.

Metaphysical or theological emergence

Emergentist theologies take several different forms, some focusing on emergence within the world, and some on emergence and the nature of God. Regarding the former, three forms are possible, here listed in order of increasing strength of divine involvement.

(1) The process of emergence might represent a basic feature of the natural world. Fundamental laws and constants and the nature of matter and energy are such that increasingly complex entities and states of affairs are formed, and more complex systems naturally give rise to new emergent properties. The emphasis is on the lawlike nature of the process: Once such basic features are set, emergence will occur naturally. It may have no broader significance outside itself.

(2) The same view of emergence being presupposed, a teleological dimension might be added. God established these features with the intention that the world would produce ever more complex entities and properties, such as complex biochemical molecules, living organisms, and the brains of the higher primates, as well as culture, art, philosophy, and perhaps religious understanding. In all cases, the pattern of complexification, once the preconditions are given, requires no divine intervention to be carried out.

(3) God might be more directly involved in bringing about emergent levels of reality. This might involve a general "lure," a constant introduction of creativity into the natural process, as argued by Whitehead and most process thinkers; it might involve the claim that in nature emergent levels (life, experience, self-consciousness) would not have occurred except for the role of God; or, the theist may assert, the entire process reflects God's providential role in history,

working the divine will in to mold reality to God's image, for example, bringing about humankind in the image of God (*imago Dei*) through God's constant creative or redemptive activity.

It is important to note that one can advocate an emergence theory of the natural world without maintaining any emergence within God. Thus one might hold an Augustinian view of God, such that God is completely immutable and dwells in a timeless eternal realm, yet through an act or series of acts preordained before creation God brings about its emergent history (its levels of emergence). On this view, emergence is divinely caused and entails a temporal process in the world, but it does not entail any change in God (Ernan McMullin).

Various forms of dipolar theism allow emergence within God, without asserting that "God comes into being" along with the process of emergence of the cosmos. So, for example, the essential or "antecedent" nature of God might be eternal and unchanging through the cosmic process, whereas the "consequent" nature of God—the side of God that interacts with and responds to the world—grows, develops, and even changes over the course of cosmic history. There is emergence within God at least in the sense that the divine experience becomes richer, containing experiences and responses that were not there *ab initio,* even though the essential nature of God remains constant.

Finally, the strongest forms of "emergentist theism" maintain that God comes to be along with the process of history. The world and the divine are inextricably wed: Where there is no world, there is no God. The world and God then come into being together, and perhaps the process will culminate in a deification of the world through this identity or association.

See also AUTOPOIESIS; COMPLEXITY; SUPERVENIENCE

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PHILIP CLAYTON

EMERGENCE OF CONSCIOUSNESS

See COGNITIVE FLUIDITY; COMPLEXITY; EMERGENCE

EMERGENCE OF LIFE

See EMERGENCE; LIFE, ORIGINS OF

EMPIRICISM

The term *empiricism* describes a philosophical position emphasizing that all concepts and knowledge are derived from and justified by experience. Empiricists disagree on the nature of experience, including whether it is individual or social and whether sense experience is to be emphasized. Empiricism often is associated with other positions, including nominalism, naturalism, materialism, atheism, secularism, humanism, behaviorism, and emotivism.

Empiricism usually contrasts with views that truths can be derived from tradition, Scripture, revelation, intuition, or reason. Empiricists often have a special attitude toward mathematics, acknowledging its role in understanding the world yet denying that it gives direct truths about the world apart from experience. In the last third of the twentieth century, Anglo-American discussion has tended to contrast empiricism with holism or coherentism.

Classic empiricism

Despite earlier roots, empiricism really began with the seventeenth- and eighteenth-century British philosophers John Locke (1632–1704), George Berkeley (1685–1753), and David Hume (1711–1776). Locke rejected the existence of innate ideas, including truths of religion and morals and held that the mind is a "blank slate" at birth. All of one's ideas are derived, either directly or indirectly, from either sensation (the source of one's knowledge of external objects) or reflection (the source of one's knowledge of one's mental processes). Berkeley, holding that perception requires a perceiver, developed a theory that required individual minds and God as perceivers of the world. Hume pushed empiricism in a skeptical direction, questioning beliefs in causation, self, and God.

Early in the twentieth century, the Vienna circle of logical positivists made a major impact on philosophy in England and the United States. They used empiricism as a criterion for meaning, holding that the only meaningful propositions are either tautologies (including mathematical statements), which tell nothing about the world, or else statements that are empirically verifiable. Logical positivism ran into two problems: It was difficult to state the principle of verification precisely, and it had a self-contradiction at its heart because the criterion of meaning is neither a tautology nor empirically verifiable. Thus the criterion of meaning seems to be meaningless. The later holism of American philosopher W. V. O. Quine (1908–2000) also challenged the positivist distinction between tautologies and empirical statements, pointing out that meanings may vary so much between contexts that the dichotomy is hard to maintain.

American empiricism

In the United States, William James (1842–1910) and John Dewey (1859–1952) developed an empiricism (called *radical empiricism* by James) that challenged some of the assumptions of British empiricism, especially the commitment to the existence of separate sensations. James held instead that people experience complexes of sensations in a matrix of relations. Thus they are not left with a choice between Hume's world of separate pieces and the non-empirical containers of these pieces (mind, God) of idealism. Values, the worth of things, can be perceived. Thus values are not subjective and arbitrary additions to empirical facts as held by most empiricists (and by modern culture generally). Dewey's subject-object transactionalism avoids the subject-object dichotomy. This more "generous empiricism" has influenced such thinkers as Henry Nelson Wieman, Bernard Meland, William Dean, Nancy Frankenberry, and Jerome A. Stone. Later Quine held that since empirical propositions are embedded in a network of commonsense or scientific theories, no statement can be verified in isolation. Confirmation or disconfirmation always affects a range of theories.

That vast conglomeration of ideas typically labeled *postmodern* has also impacted empiricism. A common theme of postmodernism is that there is no theory-free observation, that theories are not completely determined by data, and consequently that science is merely one of the many stories that people can tell each other. A major task confronting people who value science is how to honor the insights of postmodernism, including the tentativeness of verification and the hegemonic motive of the Enlightenment grand narrative of progress toward rationality, while at the same time articulating the ways in which scientific procedures have a relative and tentative yet significant value. A number of thinkers work towards this, including Richard Bernstein, Frederick Ferré, Susan Haack, J. Wentzel van Huyssteen, Lynn Hankinson Nelson, and Robert Neville.

It has been asked whether human gender influences empirical procedures, either through biological or cultural factors. Sandra Harding, Helen Longino, Evelyn Fox Keller, Lynn Hankinson Nelson, and others have been pursuing this question from differing perspectives.

Cross-cultural perspectives

To turn to a cross-cultural analysis, it should be observed that in developing their various technologies all cultures seem to have pursued empirical methods, sometimes in combination with non-empirical approaches. However, only the Western philosophical tradition seems to have developed the exclusiveness of empiricism as a theoretical option. In South Asia the Carvakas, Nyaya-Vaisesikas, and early Buddhists might be classified as empiricists. In China, Korea, and Japan the principle of "the investigation of things" occasionally took an empiricist direction, although not with the exclusiveness of European empiricism. "The investigation of things" usually included an investigation of the worth of things. One might speak of the empiricism of Mozi, Xunzi, Wang Fuzhi, Yan Yuan, Dai Zhen, and others of the "Investigations Based on Evidence" movement, and of the Korean Yi Yulgok.

Empiricism in the science-religion dialogue

As for science-religion issues, the topic of empiricism relates to virtually every question. For example, ideas on God, the soul, heaven, or reincarnation will be greatly influenced by a person's stance toward empiricism. That stance will also affect a person's ideas on the questions of the worth of tradition, revelation, scripture, or reason in religion and ethics. Related questions are whether the divine or the sacred as a quality of natural processes can be appreciated or responded to, as some "religious naturalists" hold, and whether such awareness is a complement to or an extension of a more strict empirical method. Another approach is to ask whether religious ideas can be vetoed by empirical procedures, whether they must be strictly based on or may be more loosely informed by them, or whether science and religion are such distinct orientations that neither can interfere with the other. Writers such as Douglas Clyde Macintosh and Henry Nelson Wieman have attempted to treat theology as an empirical study. The success of this depends on how one conceives God and also empirical method.

See also COHERENTISM; POSITIVISM, LOGICAL

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JEROME A. STONE

END OF THE WORLD, PHYSICAL

See COSMOLOGY, PHYSICAL ASPECTS; ESCHATOLOGY

END OF THE WORLD, RELIGIOUS AND PHILOSOPHICAL ASPECTS OF

Beliefs in the "end of the world" (loosely speaking, *eschatology*), generally from a massive cataclysm, appear in many cultures, especially those with creation myths. Those who believe this "end of the world" is imminent, that is, *apocalyptic* believers, have produced a vast literature focused on the destructive nature of the "end" of the physical creation. By creating this "sense of an ending" these catastrophic scenarios knit up a culture's cosmogony in a great cycle of time during which creation "lives out" its allotted span. Because the physical world of time and space (Latin *saeculum,* which in French, *siècle,* means both "century" and "secular") are so concrete, the temptation to measure the length of the world's existence and hence to "date" its end has existed in all cultures. Nowhere, however, did this concern become more intense than in Western European culture, birthplace of modern notions of time and modern techniques of time measurement.

End-time calculations and great cycles

These "great cycles" generally take some combination of two forms: the circular and the linear. In circular cosmogonies, the most widespread variant, creation goes through cycles from origins to annihilation and then to a new beginning, repeating indefinitely. These cycles tend to be extremely long, measured in chronological units ranging from the

Roman and Greek *millennia* (one thousand years), to the Babylonian *sar* (3,600 years), to Hindu *kalpas* (8.64 billion years). From such cycles, people looked upon the yearly cycle as a microcosm and celebrated the completion and new beginning of a cycle as a "myth of eternal return." Greek philosophical thought leaned heavily toward cyclical cosmologies in which everything repeated, or even replicated exactly, the details of the previous cycle *ad infinitum*.

In the less common linear cases, the current cycle receives a teleological significance, rendering it unique among ages, or even making it the only created age. Thus the "end of the world" becomes an ultimate moment in a divine scheme. In monotheism, with its typically moral focus, the "end" brings a *Last Judgment* in which the good receive their reward and the evil their punishment. This radical shift from circular to linear time sometimes involved equally significant shifts from viewing the passage of time as a declining process to a progressive one, looking *forward* to a golden age. Characteristically, adepts of these linear, moral schemata tended to shorten the time separating the present from the "end of the age," thus intensifying the imminence of judgment.

In both linear and cyclical cases, the future end of the world had more than merely conceptual significance to various degrees, depending on what trends these schemata attributed to the cycle, and where they placed the present in the larger process. The most prominent approach viewed the cycle as one of monotonic declension from a golden age to the current (worst) age. Often these schemes placed the present time toward the middle of the final age. In the most extreme case, Hindu scriptures (e.g., *Surya Siddhanta*) place the beginning of the last and most debased cycle, the *kaliyuga,* in 3102 B.C.E., placing the present in the early millennia of that *yuga,* and the cataclysmic "end" some 420 *millennia* away. The final conflagration in these scenarios often appears as both a destructive and a purging flame that wipes out impurities and reunites creation with eternity. Greek and Roman ideas of these cycles appear in most philosophical schools (Pythagorean, Platonic, Stoic), although the associated cycles are measured in chronological units taken from Babylonian astronomical calculations, but significantly reduced. Drawing on the second-century B.C.E. Babylonian astronomer Berossos's 12,960,000-year cycle, the Roman statesman and author Cicero (106–43 B.C.E.) dated the *magnus et verus annus* (the great and true year) to 12,954 years.

With more careful astronomical observation, calculators in antiquity increasingly tried to measure more precisely both the yearly cycle (that inelegant 365.242199 days) and the greater cosmic cycle from creation to end of the world, thus wedding cosmologies of religious importance to measurement and calculation of time. In both the case of the (liturgical) year and the (apocalyptic) cycle of the age, this attention to time played a major role in religious passions attached to the celebration and innovation of collective rituals, and from there in cultural identity formation and the widespread emergence of new religious movements that proliferated throughout late antiquity. This close connection between temporal measurement and religious beliefs and behaviors also participated in a crucial shift from cyclical to linear models and from distant to closer (more apocalyptic) end-times. These developments have a particular vigor in the Hellenistic intersection between the "scientific" spirit of Greco-Roman culture and the apocalyptic spirit of Jewish and Christian culture.

Whereas Chinese chronographers affixed a length of 23,639,040 years to a great (astronomical) cycle, and the Hindus attributed 4.32 million years to a single *mahayuga,* Near Eastern and Mediterranean cultures measured in the more restrained *millennia* and counted ages within a cycle by sevens (planets) or twelves (zodiacal signs). Among the many variants, the six- or seven-thousand year cycle proved most popular and found adepts in Mithraic, Mazdean, Jewish, and Christian circles. The marriage of astronomical cycles from Zoroastrian sources in Babylon to the linear eschatology of the exiles from the tribe of Judah (sixth century B.C.E.) produced the most vigorous strain of calculations of the approaching end. During the last quarter of the first millennium B.C.E., Jewish writers produced a rich and innovative literature of apocalyptic visions anticipating an imminent cataclysmic transformation of the world.

Theodicy and the Last Judgment in monotheistic eschatologies

For Jews and later for Christians and Muslims, end-time beliefs offered an answer to the monotheistic problem of God's justice (theodicy). These personal and morally charged visions looked *forward* to an imminent apocalyptic "Day of Judgment" that would separate out those evil people who will go to destruction and those good who will receive cosmic rewards. This intensified focus on justice and reward shifted some of the great-cycle thinking from that of the world's end to its continuation, here become a messianic age of peace and prosperity (millennialism). In any case, these eschatological beliefs, driven by a moral and social urgency, preferred shorter timelines. By the later Hellenistic age, Jewish and, still more avidly, Christian circles focused on a world cycle of a millennial week of seven thousand years. In this reading, which dramatically reversed the more pessimistic visions of the creation cycle, the current age was made up of six 1,000-year "days" of toil and travail, and looked forward to the advent, in the year-6,000 *annus mundi* (The year of the world [the year since creation]), of a sabbatical millennium, or thousand-year period of messianic peace where swords turn into plowshares and spears into pruning hooks.

Calculations of the imminent apocalyptic advent of a messianic age, based on prophetic signs, astronomical calculations, chronologies (especially based on Daniel) proliferated around the turn of the common era. Despite the invariable failure of such calculations, believers (in Islam they are known as the *exact men*) continued to engage in them, posing serious problems for those who tried to control the unpredictable explosions of strange behavior that accompany apocalyptic beliefs that "the end is at hand." One rabbi, reflecting on the catastrophes brought on by those who prematurely announce the end, cursed those who calculate the end (*Sanhedrin,* 97b), and Augustine of Hippo (354–430) commanded these types to "quiet their busy fingers," that is, stop counting (*The City of God,* 18.54.2).

The desire to "date the end" became especially vigorous in Christianity, which, from an early age (c. 100 C.E.) openly associated the apocalyptic moment with the chronological date of 6,000 *annus mundi*. Early-third-century chronographers produced the first widely accepted Christian era, *annus mundi,* calculating the years since creation based on figures in the Septuagint (the Greek translation of the Hebrew Bible, at significant chronological variance with the Masoretic Hebrew text). These chronographers located the incarnation at 5,500 *annus mundi,* their present at 5,700, and the advent of the sabbatical millennium for 6,000 (500 C.E.), some three centuries off. This open and explicit textual commitment to a date, even though at the time it might have seemed far away (though not to Hindus), wedded both *computus* (Easter dating) and chronology to apocalyptic expectations and encouraged a peculiar Christian obsession with dating that intensified at the approach of various end-time dates (500 C.E.; 801 C.E.—the second "year-6,000" *annus mundi*; 1000/1033 C.E.; 1260 C.E.; 1500/1533 C.E.; etc.). A "fever of computation," as one modern historian has termed it, appears repeatedly in the scriptoria of medieval Europe (500–1500) and marks one of the most striking aspects of Renaissance science and historiography.

End-time beliefs and scientific thinking

Western notions of the end of the world have paradoxically provided fuel for scientific developments, irresistibly urging people to "date" the end as accurately and imminently as possible on the one hand, and invariably producing failure on the other. For example, motivated by his concerns about the approach of the next "year-6,000" *annus mundi* (801 C.E.), the English historian and theologian Bede (c. 673–735) worked intensively on problems in chronology and, among other things, solved the problem of the Easter cycle: 532 years (*de temporum ratione,* On the reckoning of times), a feat that had escaped the computists of antiquity.

The obsession with measuring the end never abated, not even with the advent of a supposedly more rational age. Repeatedly chronographers (including Isaac Newton) computed the end, and repeatedly they were wrong. Each failure, however, produced a sharper, more extensive knowledge of chronology and the calculations of time, making time measurement one of the distinguishing obsessions of the West. Thus, precision time measurements, one of the hallmarks of all scientific and historical work, may well be the unintended consequence of failed apocalyptic calculations, which left in their wake a religious disappointment and refined the tools for time measurement now available for other uses, a process that evolutionary scientists call *exaptation*.

At another level, the constant failure of cataclysmic eschatological scenarios gave increased credibility to more millennial notions of a redeemed and transformed physical world. The Western fascination with "progress" and the "new" draws much of its inspiration from a notion that the future held not decay and destruction but renewal and rejoicing. This fairly unusual cultural optimism, where one sought to transform the world rather than date its end, whose most striking early expressions are primarily (though not exclusively) biblical, played a central role in the emergence of modern science, especially in the earliest centuries of the printing press.

Similarly, the failure of apocalyptic expectations may have contributed to a de-enchantment or a demystification of the ways in which Westerners have "read" the universe. No religious belief is more subject to "objective" disconfirmation than eschatological calculations, especially the specific, apocalyptic ones. These beliefs tend to excite a state of exegetical arousal, in which all observed phenomena become part of a coherent and urgent pattern of meaning. With the collapse of expectations, a cognitive dissonance ensues, which generates a wide range of behavior, some of it increasingly grounded in a focus on neutral "observation." After the immense disappointment of the Joachite year 1260, the Franciscan monk Salimbene (c. 1221–1288) wrote in his *Chronicle*: "I have sworn to believe only what I see with my eyes." The difference between Danish astronomer Tycho Brahe's interpretation of the nova of 1572 as a sign of the imminent *Parousia* (the Second Coming of Christ), and his assistant Johannes Kepler's more clinical treatment of the 1604 nova, illustrates the kind of de-eschatologizing shifts that such failures of expectation might inspire. Furthermore, this renunciation of eschatological schemata, forced by repeated and quite precise failures, may have contributed over time to the emergence of non-teleological notions (such as inertia and evolution), that have proved so fruitful in scientific inquiry.

Beliefs in the "end of the world" also played a villain's role in the persecution of scientific thinking in the medieval period. One of the major conflicts for philosophers who sought to reason about the nature of the universe concerned whether the cosmos, the physical universe, was created (and hence had an end) or eternal. Drawing on Aristotelian works, some philosophers—most notably the Arab philosopher Averroës (Ibn Rushd, 1126–1198) and the Flemish philosopher Siger of Brabant (d. 1284)—argued that the physical world was eternal. This contradicted the eschatological claims that, with their lurid threats of coming punishment for evil deeds, played a critical role in the moral education of Christian and Muslim societies. This built-in friction between rational (scientific) and revealed (theological) approaches to the physical universe provoked the repression of philosophical inquiry in the Arabo-Islamic world (and perhaps also in rabbinic Judaism). In Latin Christendom, however, despite determined efforts in inquisitorial circles to eliminate such teachings (most famously in Paris in the 1260s to 1270s, with the attacks on Siger of Brabant and the "Latin Averroists"), these dissident forms of thinking persisted and developed.

Ironically, after having hindered scientific thought for centuries, the medieval framework has, in some sense, returned to modern scientific cosmology, including both a creation (Big Bang) and some sort of cosmic destruction (either of the Earth when the sun goes nova, or of the entire universe). Of course the periods of time involved are immense—the universe is about ten to twenty billion years old, or, in Hindu cosmology, about three to five *kalpas* (4.32 billion years). Even the period left to our solar system (five billion years) makes any imminent framework for apocalyptic beliefs impossible, thus driving a scientific wedge between the monotheistic pair: the end of the world and the Last Judgment.

The ironies of modern technology of destruction

Unfortunately, what becomes conceptually inconceivable (the natural end of the world any time soon) has reappeared in a new form of unnatural ends, especially the threat of nuclear weapons and other technological agents of mass destruction. This ironic and extremely dangerous relationship of technological development to end-time beliefs is best understood within the context of millennialism, but expectations of the end of the world also play a significant role. Briefly in Western Europe, where these beliefs have been especially widespread, each disappointed expectation of God's intervention in human history seems to have inspired believers to take on more and more of the task of bringing about the apocalypse (from passive to active apocalypticism), repeatedly driving technological innovation well beyond the limits of what necessity demanded. Already in the later thirteenth century, Roger Bacon (c. 1220–1292), a younger contemporary of Salimbene and a fellow Franciscan, argued that science would provide an apocalyptic defense against the Antichrist, allowing the Church to spot the Antichrist's deceptive miracles, which he will perform using scientific techniques.

In particular, the awesome power of the atomic bomb inspired end-time imagery from one of its inventors, the American physicist Robert Oppenheimer (1904–1967). As he watched the first test bomb explode, he thought of a line from the Bhagavad Gita: "Now I am become death, the shatterer of worlds." Moreover, the arming of these weapons in the United States occurred in Amarillo, Texas, where a community of "pre-millennial dispensationalists" (passive cataclysmic apocalyptic) believed that in so doing they advanced divine plans for the time of the "tribulation." At the turn of the third millennium in a period of rapid and penetrating globalization, more active cataclysmic apocalyptic groups like the Japanese Aum Shinrikyo and the Muslim Al Quaeda have tried to make the use of these weapons of mass destruction a focus of their "redemptive" violence—destroying the world to save it. At the approach of 2000, astronomical warnings and popular films (e.g., Michael Bay's *Armageddon* and Mimi Leder's *Deep Impact*) depicted the Earth threatened by an extinction-level catastrophe, with the destructive power of modern science then arrayed in defense of human beings. Thus, while many Western Europeans may have awaited the end of the world in *anno Domini* 1,000 only to be disappointed, after the year 2000, when most intellectuals no longer believe in a God who intervenes in history, humans live, perhaps permanently, in the shadow of their own ability to destroy themselves, their own humanly wrought end of the world.

See also ESCHATOLOGY; MILLENNIALISM

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RICHARD LANDES

ENTROPY

Entropy is a thermodynamic quantity whose value depends on the physical state or condition of a system. It is useful in physics as a means of expressing the Second Law of Thermodynamics. That is, while the law may be stated in terms of it being impossible to extract heat from a reservoir and convert it totally to usable work, in terms of entropy the law states that any changes occurring in a system that is thermally isolated from its surroundings are such that its entropy never decreases.

This behavior corresponds to the fact that entropy is a measure of the disorder of a system. On average all of nature proceeds to a greater state of disorder. Examples of irreversible progression to disorder are pervasive in the world and in everyday experience. Bread crumbs will never gather back into the loaf. Helium atoms that escape from a balloon never return. A drop of ink placed in a glass of water will uniformly color the entire glass and never assemble into its original shape.

Entropy as a measure of disorder can be shown to depend on the probability that the particles of a system are in a given state of order. The tendency for entropy to increase occurs because the number of possible states of disorder that a system can assume is greater than the number of more ordered states, making a state of disorder more probable. For example, the entropy of the ordered state of the water molecules in ice crystal is less than it is when the crystal is melted to liquid water. The entropy difference involved corresponds to the transfer of heat to the crystal in order to melt it.

It may appear that there are exceptions to the general rule of ultimate progression to disorder; the growth of crystals, plants, animals, and humans are all remarkable examples of order or organization. However, these are open systems that exchange matter and energy with their surroundings for their growth and sustenance. If a composite of the system plus its environment is considered, then it can always be shown that its entropy will never decrease, as long as the composite system is isolated.

Entropy is defined in physics as the ratio of the heat absorbed by a system to its absolute temperature (i.e., temperature based on the Kelvin scale). When a certain amount of heat passes to a system from one at a higher temperature, the entropy of the two systems combined increases. This is an irreversible process characterizing the general tendency of matter to seek temperature equilibrium, a state of maximum entropy or disorder.

This progressive tendency of nature toward disorder has been considered by many scholars as one of the primal natural processes that serve as a gauge for the irreversible nature of time. Accordingly, a considerable number have identified the relentless increase of entropy with what they term the *thermodynamic arrow of time.* In addition, the degradation associated with the increase of entropy has been discussed by some scholars of science and religion as a meaningful metaphor for evil.

See also DISORDER; THERMODYNAMICS, SECOND LAW OF

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ENVIRONMENTALISM

See ECOLOGY; ECOLOGY, ETHICS OF; ECOLOGY, RELIGIOUS AND PHILOSOPHICAL ASPECTS; ECOLOGY, SCIENCE OF

EPISTEMOLOGY

The need for an entry on epistemology—the theory of knowledge—illustrates the important mediating role of philosophy in key aspects of the science-religion interface. More specifically, the problems occasioned for religious traditions by the rise of science have extended beyond particular disputes to a more pervasive sense that science stands as the measure of all valid knowledge. The result has been a significant questioning as to whether religious traditions can still be viewed as routes to truth. For those seeking to maintain that these traditions can be so viewed, and that the sciences might even profit by appropriating some of the practices of wisdom enshrined therein, epistemological analysis is inescapable.

A number of interrelated issues apply: What is knowledge? What can one know? Does knowledge require certainty, and how can one know?

What is knowledge?

Taking these in order, the standard philosophical definition of knowledge is that of justified true belief. The need for justification and the related concern for its mode of operation links to the fourth issue listed. The need for true beliefs raises the question as to what truth is in regard to propositions. There are three standard approaches: the *correspondence,* the *coherence,* and the *pragmatic*.

The instinct behind correspondence views of truth—whether in scientific or religious contexts—is that true propositions bring something of reality to conceptual articulation. Despite the lasting importance of this instinct, questions exist about the adequacy of the metaphor of correspondence. How in the scientific context, for example, can concepts be thought to correspond to an intrinsically unconceptualized material reality? Does this not inevitably trade off the assumption that real knowledge, although unavailable to humans, is of an intuitive, unconceptualized form? And does that not in turn inevitably serve to denigrate the only forms of knowing of which humans are capable?

Implicit in the above statement of the instinct behind so-called correspondence approaches is the recognition that no one proposition can be fully adequate to the complexity of even one aspect of reality. For their part, coherentist approaches maintain that the best guide to truth consists in the maximally coherent configuration of all relevant statements pertaining to a given aspect of reality. Further, to the extent that all aspects of reality are viewed as being interrelated, coherentist approaches tend towards the aspiration for the maximally coherent configuration of all possible information pertaining to all aspects of reality. In scientific terms this might equate with the heuristically useful, although unattainable, hope for a perfected science and in Judeo-Christian terms with the hope for the eschatological gathering, fulfilling, and true configuring of all things in God.

Integrating the diversity of pragmatist views is the conviction that standard truth talk requires expanding to reflect the fact that human engagement with reality extends beyond the concern to know reality aright to include also the concern to live within it well: Truth is a matter of practical action as well as of conceptual articulation. This resonates with the emphasis within religious traditions upon the need to integrate attentiveness, discernment, and wise practice. While the sciences are justifiably viewed as the clearest example of the human capacity for knowing the world, the scientific community may have something to receive here in the form of a more explicit attentiveness to the specific practical objectives and potential applications of any proposed research project.

What can one know?

The question "What can one know?" has traditionally been answered in two different, but perhaps ultimately complementary, ways: the realist and the idealist. The strong realist maintains that knowledge must involve a real knowing of the world as it really is. The idealist maintains that human knowledge can only ever be a knowing of reality as mediated by human concepts. The bind for both science and religion has been to be caught between a strongly realist-correspondentialist definition of truth and the recognition that all truth claims are inextricably shaped by human concepts. Much philosophy of science has sought to counter the charge that science is simply a useful construct that does not actually convey knowledge. Likewise, much philosophical theology sets itself against the charge that religion is simply a human mythic creation or emotive projection.

A potential way beyond the realist-idealist impasse lies in the dual recognition that while all human engagement with reality is mediated by concepts, such concepts themselves reflect a long process of interaction with the world and, for the religious domain, with the reality of God in such a fashion as renders them at least partially adequate to the reality of things.

Knowledge and fallibility

The move to any such critical-realist position clearly requires one to relinquish an absolute connection between certainty and knowledge. As noted earlier, however, principles already exist that encourage one to view both scientific and religious knowledge in its full and final sense more as an aspiration than a present reality, and this without devaluing the partial knowledge already available. Recognizing the fallibility of scientific knowledge should keep science open to revision. So also, recognizing the inexhaustible richness of God should keep religious understanding open to there always being more.

Two different constructional metaphors have been offered in response to the question of how one can justify one's beliefs: that of a building resting on sure foundations and that of an interconnected web, the strength of which derives from mutual support between members. In spite of their dominance throughout much of the eighteenth, nineteenth, and even twentieth centuries, foundationalist models of justification have tended to recede, along with the strongly correspondential definition of truth with which they are associated, as the inextricable role of language and concept in all human engagement with reality has emerged more broadly into view.

Quite apart from the unrealizable character of foundationalist aspirations, alternative systemic, coherence-based approaches to justification have been claimed to fit the actual practices of scientific and religious reasoning better. It can be claimed that any danger of promoting a move towards closed systems wherein coherence is won at the cost of insularity and ossification can be offset by a recognition of the permanent fallibility of present understanding and a consequent continual drive towards ever more extensive coherence.

While pragmatist views are generally seen as having a limited contribution to make to the justification of propositions, some accord them a greater role in choosing between methods of ascertaining truth. Perhaps their real value is in reminding us of the various factors that may influence someone in finding one system, rather than another, truth-bearing. While that is particularly appropriate in the religious context, it may also be more appropriate in the scientific context than many scientists care to admit.

See also CRITICAL REALISM; FOUNDATIONALISM; IDEALISM; NONFOUNDATIONALISM; POSTFOUNDATIONALISM; PRAGMATISM; TRUTH, THEORIES OF

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EPR PARADOX

EPR paradox is a seeming paradox conceived as a thought experiment by Albert Einstein (1879–1955), Boris Podolsky, and Nathan Rosen in 1935 as a challenge to the Copenhagen Interpretation of quantum mechanics. The title of the published paper was "Can Quantum-Mechanical Description of Physical Reality be Considered Complete?" Einstein did not believe that objects only had properties when they were observed. He tried to conceive of a situation in which the observation of one thing would lead to a situation in which it was one hundred percent certain that another state would be completely certain irrespective of whether it had been observed.

Atomic states can be created so that their total spin is zero. If the state is allowed to decay into two spinning particles that move off rapidly in opposite direction close to the speed of light then the particles must have spin of +1 and −1 units respectively, so that they add to zero, as required by the conservation of spin. According to the Copenhagen Interpretation of quantum mechanics the spin of either of the two particles does not exist until it is measured. Before any spin is measured any one of the two decay particles has a fifty percent chance of having spin +1 or spin −1. But EPR argued that if you measure one particle and find its spin to be +1 then you know that the other must be −1 without a measurement taking place. Einstein argued that this undermined Niels Bohr's (1885–1962) interpretation of quantum measurement. The word *paradox* became associated with this set up because it appears mysterious how the second particle to have its spin measured can "know" what the outcome of the measurement of the spin of the first particle turned out to be. However, Bohr showed that this was not in fact the case. The two particles are entangled by quantum reality in such a way that there is no violation of the Copenhagen Interpretation of quantum reality. The measurement of the spin of the first particle brings into being the spin of the second particle. More recently, experiments of this sort have been performed by Alain Aspect and colleagues in 1982 in ways that allow the predictions of quantum mechanics to be tested to see if there is any conflict with observation. So far, the predictions of quantum mechanics agree with all observations to high precision.

See also COPENHAGEN INTERPRETATION; EINSTEIN, ALBERT; PARADOX; PHYSICS, QUANTUM

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JOHN D. BARROW

ESCHATOLOGY

Eschatology, from the Greek word *eschaton* (the last), is the theological study of the last things, the final state of each individual, of the community of all individuals, and of reality itself. Thus, traditionally eschatology has dealt with the themes of death, judgment, heaven, hell, purgatory, the resurrection of the dead, the end of the world, and "the new heavens and the new Earth." Generally, eschatology deals with the ultimate destiny of individuals and creation, and what it is legitimate to hope for. For Christians, that destiny is envisioned as the resurrection of each individual with Christ and the transformation and unification of all things with him in God forever. In theological reflection since late 1960s, there has been a shift in stress to the present realities, which through God's active presence in the risen Christ and in the Spirit are considered the seeds or partial realizations of this ultimate destiny (realized eschatology). Full flowering and completion will only be achieved after death and the "final consummation" of the universe.

It is at this point that the natural sciences have a contribution to make. Biology, paleontology, geology, and astronomy help one appreciate the transience and fragility of all that exists, even though nature is continually bringing new things and new life out of dissolution and death. No individual entity or species continues forever. Cosmology assures that the observable universe itself will eventually become sterile and evanesce as it expands forever, undergoing heat death. The natural sciences are, of themselves, unable to discern anything beyond physical dissolution and biological death. However, because theologically there must be a continuity between present reality and its final transformation at the *eschaton,* certain key characteristics of reality, such as relationality and pattern, will undoubtedly be the enhanced basis for its eschatological completion.

See also DEATH; ETERNITY; LIFE AFTER DEATH

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ETERNAL LIFE

See ESCHATOLOGY; ETERNITY; LIFE AFTER DEATH

ETERNITY

The concept of *eternity* qualifies both discussion about God and about human destiny, although in different but analogous way. Most believers would profess that God is eternal and many of them believe that eternal life is the prospect of human life in the wider context of the divine life. However, believers, theologians, and philosophers disagree about the meaning of these professions. With the declaration "God is eternal" religious believers express their faith that God encompasses all time for them as creatures because divine life has all the time it needs without beginning or end. God is present at any time in the course of history; divine existence is everlasting, so it endures without any possible limitation. This notion of eternity is found in biblical literature.

The word *eternal,* meaning "everlasting," can be used in a strong and weak sense. In the strong sense it refers only to God with the entire divine reality, which always has existed and will exist without end. In the weak sense *eternal* might be used to describe creatures that enjoy eternal life that has a temporal beginning but will have no end. Human beings have their creaturely constraints (birth and death), and it is God's grace when they (or their soul) receive eternal life beyond death, which is life in relation to the eternal God. Apart from these meanings, *eternity* is sometimes used in a nontemporal way: To live *sub specie aeternitatis* means to lead one's life according to eternal ultimate normativity.

Theologians and philosophers often disagree about how to interpret *eternal.* Many of them understand "God is eternal" as affirming "God is wholly timeless." So they imagine the divine being as outside time, without a temporal location (a moment of existence), and without duration (a period of subsistence). There is an anthropological argument *pro* timelessnes, presupposing a realistic theory of time (time flows and exits independent from events) that runs as follows: Human life is limited both by the borderline cases of birth and death (moments) and by the periods of its past, which are no longer available, and of its future to which it has no access. As temporally living beings, humans are imprisoned in time, continually losing parts of their lives (present events). Such an "imprisonment" in any temporal series is considered to be a denial of the perfectness of the divine being. Therefore, the Roman philosopher Boethius (c. 480–524) equated God's perfect eternal life with timelessness: "eternity is the instantaneously whole and perfect possession of illimitable life."

So far, the argument entails that God knows everything simultaneously because the past, present, and future of God's life are instantaneously grasped in all its relations to creation. Therefore, the past, present, and future are all present to God in one divine point of view. Boethius illustrates God's point of view outside of time with the image of a person standing on a mountaintop who sees what happens along the road in the valley. That person sees, as it were, simultaneously the past, the present, and the future of people walking along the road. The mountain metaphor, however, makes unequivocally clear that this all-encompassing simultaneity spatializes the concept of time: God observes all temporal relations between events as if they were spatial relations between objects in a landscape. If the omniscient God knows all the events of past, present, and future simultaneously, God is simultaneous both with these individual events in order to observe them, and with the sum total of these events because God must be outside of time to observe the temporal series as a unity. Because divine knowledge is true by definition, God's observation of the temporal order is how it "really" is; all events are simultaneous, synchronized. In other words, the notion of a causal chain as a temporal structure is useless because causes and effects are simultaneous, which makes the temporal order arbitrary and causal circularity a serious option. This appears to be equivalent to the assertion that time has no temporal metric and merely a spatial topology. Given this reconstruction, time is merely illusion or appearance (in line with an idealistic theory of time). And therefore, the temporal "imprisonment" human beings might experience is illusory as well. Without coping with such issues, a timeless view of God's eternity is incoherent.

For classical theists, however, eternity conceived as sempiternality (of never-ending duration) raises several theological problems. Divine essence cannot be identical with existence because a temporal God continually loses part of being as past and is not fully actual because of the divine future. Moreover, a temporal God cannot be simple because the divine existence is composed of past, present, and future, each with its own logic. Lastly, to reach the present for a sempiternal God takes an infinite amount of time, subdividable in a finite and an infinite part *ad infinitum.* These interpretations of essence and simplicity, however, are disputed, whereas the third issue misses the existential point that there is no moment in history in which God is absent. The use of temporal language has the advantage that it can make sense of the notion of divine action and involvement in history.

Contemporary theologians like Wolfhart Pannenberg (1928–) and Jürgen Moltmann (1926–) argue that God's future already exists (in a tenseless sense) from which God acts in the present, a movement opposite to the arrow of time. So God's eternity is an entering in time in which everything is shaped by and from God's future, which is declared to have ontological priority over past and present. However, God's action from God's future implies that all past, present, and creaturily future are simultaneous with God's future. Thus, in God's view, the complete history of created reality appears to be a timeless block universe, whereas from the perspective of creatures history is experienced as temporally ordered. Pannenberg interprets the divine eternity as simultaneity, the perfect possession of the fullness of life, which is claimed to be the opposite of timelessness. Both the whole of creaturely history and this divine life is present to God in such a way that God's eternity embraces the totality of time.

See also LIFE AFTER DEATH; TIME: RELIGIOUS AND PHILOSOPHICAL ASPECTS

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ETHICS

See ALTRUISM; MEDICAL ETHICS; MORALITY; TECHNOLOGY AND ETHICS; VALUE

ETHNICITY

This entry probes the intersections of religion and science from a cultural perspective. Culture and ethnicity are crucial to the ongoing dialogue about meaning, nature, and the role of humankind in the cosmos, Historically, it was assumed that dominant cultures provided the only reliable scientific methodologies and theological interpretations. This preoccupation with rationality, objectivity, and neutrality relegated the wisdom of indigenous people to myth and mystery. Yet scientific findings are more congruent with ancient wisdom than modernist deductions. Ancient intuitions hint at a universe that is expansive rather than exclusive, connected rather than isolated.

Both religion and science offer intriguing insights about the universe, culture, and human nature. Both disciplines, however, have been complicit in the oppression of racial/ethnic people. Historically, religion was used as a catalyst for domination, wars, atrocities, and abuses of humankind are still perpetrated in the name of God. In North America, Christian slave masters hoped that Christian conversion would encourage slave to accept their fate. The promise of freedom in heaven relieved owners of the need to redress immediate and grievous breaches of human rights. During the civil rights movement, it was the unified efforts of local clergymen who urged Martin Luther King Jr. to slow his initiatives for justice.

Theological discourses also rely upon problematic dyads of light and dark to signify good and evil. This is done even though biblical texts refer to a God who is identified with light but who also dwells in darkness. People live in a world that is seduced by light, intrigued by its properties, and theologically persuaded that evil is synonymous with darkness. This paradigm allows people with dark skin to be deemed pariahs and strangers within the world community.

Despite cultural assumptions to the contrary, most scholars agree that race is not a biological or physical category, yet racial perceptions persist. Race always develops within a matrix of superiority and inferiority. Distinctions based on color, physical traits, or ethnicity mask issues of power, fear of difference, and social control. Those who envision an egalitarian society in the twenty-first century will be challenged to use all of the resources at hand to deconstruct mythologies about race.

Seekers of justice usually rely on the discourses of religion to describe their visions of freedom and reconciliation, but reject the metaphors of science when they try to delineate the contours of the beloved community. Even though both science and religion incorporate issues of power, hierarchy, and the assignment of inferiority, ethnic communities have a historical mistrust of scientific contributions to issues of race.

In scientific circles, eugenics attempted to tie social constructions of inferiority to physical attributes. In the eighteenth century, Swedish botanist Carolus Linnaeus (1707–1708) created "scientific" racial classifications and descriptive characteristics. In the nineteenth century, Louis Agassiz (1807–1873), a Swiss-born Harvard professor, argued that human beings do not share a common ancestry (monogenism); instead, he argued that God created the races as separate and distinct human categories (polygenism). On the medical front, the Tuskegee Syphilis experiments conducted at the Tuskegee Institute in Alabama from 1932 to 1972 allowed syphilis to advance untreated in African-American male subjects despite the eventual availability of penicillin. Nazi experiments on Jewish prisoners are also ignominious moments in history.

The sciences also influence social institutions, laws, and theological perspectives. As physicist Nick Herbert notes, Isaac Newton's description of the world "as a giant clock" was translated in cultural contexts into "atomicity, objectivity, and determinism" (p. xi). A rigid and mechanistic view of the universe influenced political and social initiatives that oppressed those deemed to be at the bottom of the hierarchy. The case can be made that both science and religion can reflect the best and the worst in human culture.

Despite these problems, the quest for justice is not just a social and spiritual construct; it also reflects the view of the universe and the human task within the cosmos. Accordingly, liberation initiatives require the resources of both science and religion. The questions change when science and religion inform discussions of race and ethnicity. What does race mean in a scientific context, when darkness is no longer an indicator of inferiority, but instead becomes a cosmological metaphor for the power and predominance attributed to dark matter? Biology teaches that social separations based on difference are false. People are connected through a common human ancestry and genome. Cosmology teaches that separation is not the way of the universe. Instead connections that defy rational processes abound. By means of the Uncertainty and Complementarity Principles, physics demonstrates that observations and attempts to know other humans connect people at the most fundamental levels.

Conflicts based on race, ethnicity, gender, class, or sexuality are power struggles that attempt to define social acceptability through force or appropriation of the public narrative. The addition of religious and scientific concepts and discourses offer a rhetorical corrective to social and legal theories about life in diverse and multicultural spaces.

See also ANTHROPOLOGY; EUGENICS; LIBERATION THEOLOGY; WOMANIST THEOLOGY

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EUGENICS

Eugenics is a science that aims to purify the gene pool, especially of humans, by controlling reproduction to assure the birth of offspring with desired traits. The roots of eugenics go back to ancient Greece, where Plato's *Republic* lauds procreation by the best parents. The term *eugenics,* derived from the Greek word *eugenes* (good in birth), was first used in 1883 by the British scientist Francis Galton. Advocates of eugenics sought to counter Charles Darwin's theory of natural evolution with human-controlled outcomes. American biologist Charles Benedict Davenport (1866–1944), founded the Eugenics Records Office at Cold Spring Harbor, New York, in 1910. Davenport's work there led some of the first research in human eugenics during the early 1900s.

Environmental eugenicists emphasized prenatal care and a clean environment to ensure "positive" eugenics. Negative eugenics reached its apex during the Nazi regime (1933–1945) in Germany, which sterilized and murdered the "racially unfit." By the late twentieth century, eugenics and the Holocaust were linked. Yet earlier, some states and the U.S. government mandated sterilization for persons with severe genetic disabilities, and immigration laws in 1924 sought to reduce the number of immigrants from areas considered less desirable, such as eastern and southern Europe. In the 1950s, and most dramatically since the 1980s, human genetics replaced eugenics as the accepted approach to planned reproduction. Genetic counseling and sophisticated screening for genetic or chromosomal diseases or disorders inform parents about reproductive options. Will labeling fetuses "defective" or "less desirable" reintroduce selection by abortion, voluntary sterilization, or birth control? Some feminists and liberal religious groups embrace freedom of reproductive choices, while persons with disabilities, Roman Catholics, and conservative Protestants fear that it will lead to a disregard of human life from conception forward.

With the completion in the year 2000 of the sequencing of the human genome, determining genetic anomalies or, some say, even the genetic roots of destructive social behavior will trigger the wide dissemination of genetic information. Confidentiality becomes crucial. Some fear that human hubris, like that exhibited by the mythic figures Prometheus or Pandora, will engineer the engineer as well as the engine along an unknown track. Eugenics merged with genetic engineering produces scientific triumphs, moral challenges, and fears about things like human germline alteration and dissemination of pathogenic bacteria. There are dangers in policies of noninterference (as plagues and epidemics testify) as well as in genetic enhancement in which the definition and social policies establishing the "fit" are externally, rather than individually, determined. The slippery slope argument suggests that once certain traits are screened (e.g., color blindness or skin color) they will be eliminated or altered. The challenge is to determine the difference between therapeutic and eugenic measures.

At heart, one's definition of moral dilemmas surrounding eugenics is affected by one's view of knowledge as neutral or value-laden. If "improving" the human condition is a laudable end that genetic engineering can achieve, then this knowledge is good. Some believe that obligations to future generations and exorbitant health care costs provide a moral mandate to screen and treat curable diseases. Is consideration of supremely compromised fetuses, profoundly disabled persons, or comatose elderly from the perspective of financial and social burdens a sign of a highly moral society or an irresponsible one? Hermann Muller, for one, argues that the gene pool is at risk without positive eugenics, while Gregory Pence argues in *Classic Works in Medical Ethics* that even with sperm and eggs from genetically "superior" fathers and mothers, predicting "perfect" children is uncertain at best.

See also ABORTION; BIOTECHNOLOGY; DARWIN, CHARLES; ETHNICITY; GENE PATENTING; GENETIC ENGINEERING; GENETICS; GENETIC TESTING; HUMAN GENOME PROJECT; PLATO; PLAYING GOD; REPRODUCTIVE TECHNOLOGY; SOCIOBIOLOGY

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ABIGAIL RIAN EVANS

EVANGELICAL THEOLOGY

See CHRISTIANITY, EVANGELICAL, ISSUES IN SCIENCE AND RELIGION

EVIL

See EVIL AND SUFFERING; THEODICY

EVIL AND SUFFERING

Evil is whatever frustrates or opposes goodness, and goodness is what is, or ought to be, desired by conscious rational agents. Suffering is thus one sort of evil, since no conscious rational agent would desire to suffer, just for its own sake. Other sorts of evil lie in the frustration of the aims and goals of rational agents (one might also include the aims of God, and some would include the aims and goals of any beings whatsoever, insofar as they could reasonably be said to have aims or goals), or in factors that restrict the normal activities and dispositions of rational or sentient agents.

Buddhism

The faith that most obviously takes the fact of evil as one of its basic starting points is Buddhism, whose first noble truth is that “all is suffering” (*dukkha*). This is not merely the view that there is much frustration and suffering in life. It is the view that material existence essentially involves suffering, so that no enduring happiness can be found in such existence. Not only is there the obvious suffering to be experienced in birth, disease, and death. There is the fact that pleasure is short-lived, misfortune is always possible, and the transitory nature of time itself means that the past is lost forever, the present cannot be held fast, and the future is always tinged with anxiety. The one who sees deeply into the nature of things will therefore see that only in the acceptance of total transience can any stability be found. All things are empty of enduring substantial existence, and there is not even an enduring substantial soul or self that remains the same throughout all change. All things are in perpetual flow, interdependent and perpetually perishing. *Dukkha* is the first noble truth of the Buddhist way, which sees suffering and evil as the basic human problem, which may, with some difficulty, be overcome.

Buddhists are not usually concerned with answering the question of how suffering arises. It is just there, a fact of existence. However, the cause of suffering is said to be the sort of desire that consists in attachment to finite things—wishing to possess them, or bemoaning the lack of them. So it might be said that suffering is intrinsic to a world in which attachment and desire are possible. In addition, specific sufferings are caused by *karma,* by the accumulated attachments of many past existences. So it might be held that souls “fall” into this world of the senses, of transience and time, because of desire, and they have to work out the consequences of their desires over many lives until they achieve liberation from the wheel of rebirth—*samsara*—and, all desire exhausted, never again experience rebirth.

Karma and moral causality

Insofar as rebirth is essential to Buddhist belief, there needs to be a spiritual or mental part of human nature that is capable of rebirth. There needs to be a form of moral causality in nature, which ensures that actions have appropriate consequences in future lives. And there needs to be some form of correlation between practices of morality and meditation and the achievement of those higher mental states of mindfulness, compassion, and bliss, in which the practitioner approaches liberation, or *nirvana.*

To devise precise and measurable tests of these claims is, however, extremely difficult, if not impossible. Neurophysiology may lead to the establishment of links between brain and mental functions, but it is highly disputable whether it can establish either that mental functions are nothing but brain functions, or that they can have separate existence. At present, evidence suggests a high degree of correlation, in a rather general sense, between brain states and mental states. But attempts to show, for example, that there can be "out of the body" experiences, are viewed skeptically by most scientists. While claims that complete physical accounts of mental activity are possible are viewed equally sceptically by most philosophers.

Similarly, attempts to establish or disprove rebirth are unsatisfactorily vague or uncontrolled. The alleged evidence for memories of past lives is highly contested, and the theoretical difficulty of aligning souls that have highly developed propensities and desires with appropriate genetic materials may suggest that a completely new individual is created with each random combination of genetic material at fertilization, but it is hardly conclusive.

Most physicists would probably think of laws of nature as operating in an impersonal, universal, and morally neutral way, thus throwing doubt on the existence of any general principles of a morally ordered causality, which could ensure that all persons get the just deserts that their past lives have accumulated. Scientific views have developed in contexts in which rebirth has not been a major issue, and the belief is at present beyond the competence of the physical sciences to determine. It may even be held that the study of discarnate mental states is beyond the competence of science altogether. Buddhist appeals to laws of karmic consequences, and to the causal connectedness of desire and suffering, to explain the existence of evil and suffering, must be regarded as coherent and possible, even though they are in some tension with the world-view, if not with the particular established findings, of the natural sciences.

There are far less metaphysically committed forms of Buddhism that might regard belief in rebirth itself as an irrelevant question. They may not seek theoretical explanation at all, but remain concerned only with the practical question of how to overcome suffering and attain mindfulness and equanimity. In that case, Buddhism would be almost entirely a matter of moral commitment and mental discipline aiming at enlightenment. Evil and suffering would be purely practical problems, and would not be subject to scientific evaluation, except possibly for psychological tests to determine whether Buddhist techniques of meditation produce the desired results.

Hindu traditions

Belief in karma and rebirth is common to most Indian religions, and so in general an explanation of the occurrence of suffering is given in terms of the consequences of wrong acts or attachments in past lives. However, most Indian traditions are theistic, with devotion to one or more gods as central to their practice. Sometimes the gods are regarded as caught up in the cycle of *samsara* just like human beings. They have finite existences, which are much happier and longer-lasting than those of humans. But they will come to an end, and even the gods may fall down through the chain of beings into greater suffering, if they do not attain final liberation.

Those Indian traditions that are fully monotheistic (such as the two major traditions of Saivism, worship of Siva, and Vaisnavism, worship of Vishnu) usually identify the highest god with Brahman, the absolute reality, and assert that in some sense all things are one with, parts of, or expressions of Brahman. Since Brahman, appearing as the Supreme Lord, Isvara, is perfect in wisdom, intelligence, and bliss, and is the cause of the universe, there is a "problem of evil" in those traditions. The problem is how a perfect being can originate, or even be identical with, a universe so full of evil and suffering.

This is not usually felt to be a severe problem, however, since Brahman, though perfect in intelligence and bliss, contains the potentialities of all finite things in its own infinite reality, and those potentialities necessarily manifest themselves in the origination of an infinite number of worlds. The combination of a necessary manifestation of all possible realities, and a karmic law by which all finite souls receive the consequences of their own choices through a huge succession of embodied lives, effectively draws the sting out of the problem of evil. The imperfect manifests by necessity from the perfect, which remains changeless and unaffected by all imperfection. And in the realm of the imperfect, it is the acts and desires of finite souls themselves that cause both their suffering and happiness. The Supreme Lord is not responsible, and can in no way be blamed, as though he had chosen to inflict suffering on helpless and innocent creatures.

Very traditional or literalist readings of the Hindu scriptures may lead to tensions with evolutionary biology, since they depict a degeneration from an earlier golden age, when the gods were more intimately known, to the present. There may also be difficulties with belief in rebirth, since the number of human souls now in existence exceeds that of past history, and according to most scientific accounts there were millions of years when no souls existed at all. However, Hindus say that rebirth can take place in many different worlds or planes of existence. This cosmos is only one of an infinite number of worlds in which souls might be reborn in various forms. Moreover, Hinduism is not committed to literalism any more than Christianity is. In general the Hindu view is that evil and suffering arise from ignorance (*avidya*) of the truly spiritual nature of reality, and the mistaken belief that souls are essentially material. This view entails no particular account of the past history of this cosmos, since souls may have existed in other planes of being. To the extent that the natural sciences allow for such a belief in the ultimate primacy of spirit, and for belief in rebirth, and to the extent that Hindus interpret the classical myths as legendary, the Hindu account of evil and suffering as due to karmic fruits of action raises no particular problems for the relation of religious and scientific beliefs.

Semitic religions

The Semitic religious faiths (Judaism, Christianity, Islam, and their offshoots) have a different account of the human soul. They do not think, as most Indian religious traditions do, that souls exist without beginning or end, and are reborn in countless forms. They believe that human persons are formed of dust—they are material, and begin to exist with, or some short time after, the conception of a genetically unique individual. This means that the theory of karma is not available to the Semitic faiths to explain evil and suffering. Furthermore, since Semitic religions interpret creation as the freely chosen act of an omnipotent God, there is a serious problem about why there is evil and suffering in the world at all.

It could be held, and often Jews and Muslims do hold, that the creator is beyond assessment in moral terms. The divine nature is inaccessible to human understanding, and it is impious to question God or to judge whatever reasons for creating God might have. That, however, clearly raises the question of whether God can be called good. According to such a view, there are three main senses in which an omnipotent and incomprehensible creator could be called good. First, God can be good because God is the supremely desirable object of rational choice. God is desirable above all things. The divine being is unsurpassed in beauty, wisdom, knowledge, and power, and is supremely good in the sense that a beautiful picture might be called good.

Second, God is merciful and compassionate, showing mercy to thousands of those who love him, and God can forgive sins and help and support whomsoever he wills. God is also rigorously just, and will visit the sins of the fathers on the third and fourth generation of their descendents. The divine will is simply unquestionable. But God will be merciful to those who sincerely seek to obey his will.

Third, God offers incomparable rewards to the just. At the day of resurrection, he will condemn the unjust (perhaps not for ever), but grant to the just unending life in paradise, a share in the world to come, which will make all the suffering of this life as nothing by comparison.

Theodicy and science

Such a view does not seek to offer any reason why evil and suffering exist, rooting them in the unfathomable will of God. For many people it is difficult, however, to think of God as truly just when so many innocent beings suffer so much. And to some, appeal to rewards after death cannot compensate for immense suffering in life, when an omnipotent God could presumably have abolished such suffering. So attempts have often been made to justify the ways of God to men, with varying degrees of success.

At this point the natural sciences, perhaps surprisingly, offer a certain amount of help. It would be almost impossible to understand the universe if events in it did not occur in accordance with general and predictable laws. So a condition of scientific understanding, and of the growth of the ability to adapt and control our environment, is the existence of general laws of nature, which will be both mathematically precise and virtually universal in scope.

Such laws are "nested" in an extremely complex way, so that the elementary and highly unstable forces of the subatomic world form stable atoms and molecules at a higher level. These in turn form the solid bodies and organic unities that are found at the level of human perception. And they make possible the formation of central nervous systems and brains, which are the conditions of consciousness and eventually of rational agency. Thus the natural world seems to be a developing system of levels of emergence, whereby on the basis of a few elementary laws and particles complex communities of rational agents can come into being. These agents are not alien intrusions into the material world. They are its highest emergent forms, and manifest the amazing capacity of matter to come to understand and shape itself.

The development of quantum mechanics strongly suggests that there is a deep interconnectedness in nature, whereby each part is connected with every other, and it is not possible simply to remove even a few electrons, and leave the rest of the universe unchanged. In other words, one cannot just change a few parts of the universe for the better, and otherwise leave everything as it is. Either you have the system as an interconnected whole, or you have something completely different. To put it bluntly, as a rational agent, a human soul, who is an integral part of this material universe, either you exist in this universe, with all its faults, or you, as the precise and unique individual you are, do not exist at all.

At the level of biological existence, as it is presently understood, humans have come to exist largely by the operation of the principles of random mutation and natural selection. It is as if living things shuffle through the possibilities of existence, creatively seeking new forms of adaptive life. Consciousness and creativity are perhaps, as biochemist and theologian Arthur Peacocke (b. 1924) suggested, inherent potentialities or *propensities* of matter, which will be realized in time through the shuffling and adaptive processes of natural selection. Human nature is essentially the product of these processes, and the lust and aggression of humans, as well as their interdependence and altruism, has been built up through the adaptive process over many generations of evolution. Being parts and products of this natural process, humans cannot be basically different from what they are, creatures that are partly competitive and violent, and partly cooperative and loving.

If the universe disclosed by the sciences is roughly like this, its basic nature will include the operation of general laws of nature, the emergence according to such laws of consciousness and agency, the existence of humans as an integral part of a general system that cannot be different from what it is, and the gradual evolution of humans through processes of mutation and competition. Evil and suffering will be ineliminable from such an evolutionary world-system. Destruction and violence are built into the system from the decay of nuclear particles to the explosion of supernovae and the elimination of life-threatening organic competitors.

The moral of the story is that God cannot create human beings without creating a universe like this, with all its evil and suffering, of which such beings are an integral part. In this sense the natural sciences offer a sort of theodicy, the giving of reasons why a good Creator might create a universe with suffering in it. It might be wrong to think that God can create absolutely anything we can imagine—human beings in a universe without suffering, for example. There could be beings in a universe without suffering, but they would not be human. They would not be us. So if human existence is worthwhile, maybe the suffering in this universe has to exist.

For some contemporary scientists, like Steven Weinberg, human existence is not worth-while enough to justify so much suffering. Or maybe evolution is seen as too random or accidental to be purposive. To these scientists, chance and necessity are enough and rule out any idea of a good God who chooses to create the universe. But this may not be a strictly scientific judgment. A good God could create this universe, if the suffering in it is a necessary condition or consequence of an overwhelmingly great good—and such a good might be the creation of rational agents who could enjoy eternal fellowship with one another and with God.

This conclusion would be strengthened if the creation of a universe like this was somehow necessary to God, as flowing from the changeless divine nature. At this point most theists insist that the act of creation must be free, not compelled, and must be intended, not accepted reluctantly by God. But when speaking of the divine nature, the distinction between freedom and necessity may not apply—some theologians suggest that God is necessarily what God freely chooses to be. As long as God is not compelled by some external or undesired force, the act of creation may be both free and necessary—as the being of God itself may be. As Thomas Aquinas (c. 1224–1275) put it in his *Summa Theologiae*, God's willing is identical with God's essence, which is necessarily what it is. Yes, as Aquinas notes, this is compatible with God's freely creating the universe.

Thus evil and suffering may be in some way necessary to the creation of humans. In traditional terms, evil and suffering are privations of goodness, not positively intended states. This is a viewpoint to which scientific investigation of nature makes a positive contribution.

Other explanations in theistic traditions

In the Abrahamic traditions, and especially in the Christian tradition, there has always existed another explanation for suffering—it may be the result of the maleficent or egoistic actions of rational beings. Satan is an angelic being whose evil is perhaps the cause of natural evils like earthquakes, and he successfully tempted Adam and Eve to disobey God. From a primal Paradisal state, Adam and Eve were ejected into the harsh world of an already *fallen* nature. In the Western Christian view, all their descendents were born in *original sin,* guilty before God even at birth because of the sin of their ancestors. Suffering and death entered the world mainly as a result of Adam's sin, and are now punishments for moral evil.

This literalist interpretation of Genesis (not accepted in this form either by Jews or by Eastern Orthodox Christians) is obviously at odds with any evolutionary account, for which suffering and death were intrinsic parts of the biological world long before humans even existed, and for which there is no paradisal world at the beginning of human history. Most Christian theologians now regard the Genesis accounts as legendary, and reinterpret the fall in terms of a general human condition of moral weakness and ignorance of God, which was caused or intensified by the moral and spiritual failures of the first humans.

Some theologians, like Paul Tillich, regard the fall as a necessary part of human evolution, which requires an *epistemic distance* between humans and God to enable moral autonomy to exist. Others think of the primal human estrangement from God as originally due to voluntary moral failure, though now all humans are born into an estranged society, and so not onto an equal moral playing-field. In contrast to Jews and Muslims, most Christians insist that reconciliation with God cannot be achieved by good works, but requires divine grace, or some act of divine self-sacrificial love, which was manifest supremely in the life and death of Jesus.

It is generally held in all Abrahamic traditions that much evil and suffering is caused by the free immoral acts of past and present human beings. Such an account can easily be held together with a commitment to the necessary possibility of such evil, and its actual existence to some degree. Human moral evil would be seen as intensifying the amount and degree of actual evil and suffering.

Evolutionary biology requires some revision of traditional views, especially of original sin. However, it offers a helpful account of how moral failure follows naturally, if not inevitably, from the dispositions to lust and aggression that are part of the human biological inheritance and have been necessary conditions of human dominance in the processes of natural selection. On a literalist biblical account, it is hard to see why the first humans should have sinned against God at all, except by a sheer irrational act. But in an evolutionary context, sin becomes the natural expression of biologically inbred tendencies. Such expression becomes "sin" only when expressed in opposition to divine commands to love and reconciliation. One still cannot explain why humans sin—that is a free and therefore inexplicable choice. But one can give good reasons why they might sin—it is an inherent possibility of their nature, and offers temptations of sensual desire that might well, though they should not, counteract the impulse to love God, which also, according to this hypothesis, lies present, though perhaps only implicitly, in their biologically evolved nature.

A third explanation for evil and suffering in theistic traditions is that they are not the natural consequences of egoistic acts, but punishments inflicted by God for moral evil. This explanation has played a part in much religious thought, and biblical narratives often connect natural and human disasters with lack of obedience to God's law, while happiness and long life are seen as rewards for obedience. The scientific perception of laws of nature that are not morally ordered, of the chance elements involved in natural selection, and of the biological basis and the possibility of medical treatment for most diseases has largely led to the collapse of such views. In the Bible it was also perceived that God causes rain to fall on the just and on the unjust, and that the innocent suffer. Any easy equation of immorality and suffering is undermined by the Book of Job. While it is not absurd to posit a general tendency toward altruistic acts to produce happiness, and toward egoistic acts to produce suffering, the attribution of diseases to demonic influence, and of natural disasters to direct decisions of God to punish sin, has largely disappeared from informed theological debate.

Conclusion

Perhaps the greatest influence of modern science on these matters has been the supercession of belief in the direct causal acts of good and bad spirits by belief in the general operation of impersonal laws of nature. God's action in the world is largely seen in the setting up of a general system in which good is effectively selected and evil becomes finally self-destructive, rather than in continual divine interventions in nature. Particular divine actions (miracles) need not be denied, but they will be, almost by definition, very occasional transcendences of the usual processes of nature for a spiritual purpose, not the normal causes of happenings in the universe.

All these traditions accept that evil and suffering are either necessary or the result of freely chosen acts, and that in either case one should seek either to abolish evil and suffering or to overcome them by altruistic action, non-attachment to selfish desires, and perhaps by devotion to God. Science does require a reconstruction of traditional ways of formulating these positions, but it is reasonable to see the scientific view of nature as helpful in developing a deeper religious understanding of the place of suffering in the world, and offering more effective practical ways of overcoming it.

See also SIN; THEODICY

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KEITH WARD

EVOLUTION

There is a common belief that evolution and religion, Darwinian evolution and Christianity especially, are world pictures that are forever opposed. This is a belief today endorsed and promulgated both by extreme evangelical Christians (who support some version of Biblical literalism) and ardent ultra-Dawinians (who hold that their theory necessarily falls into an atheistic mode of thinking). Traditionally, however, this opposition has not been universally accepted. Many people find that there is much in common between the two systems and, thus, great opportunities for sympathetic dialogue. Much of the difficulty and debate arises from ignorance about the various positions involved. This is especially true of evolution. In discussing the idea of selection, it is convenient to make a three-fold distinction between the *fact* of evolution, the *path* of evolution, and the *theory* or *mechanism* of evolution.

The fact of evolution

The fact of evolution is simply the idea that all organisms, living and dead, came into being by a long developmental process, governed by natural laws, from organisms of a different, probably much simpler, kind. The fact of evolution includes the belief that the original organisms themselves developed by natural processes from inorganic materials. If one wanted to extend from the biological to the cosmological, one would see the fact of evolution as including all developmental change from the time of the Big Bang.

Claims for the fact of evolution were first mooted in the seventeenth century with the extension of Newtonian ideas from the mere running of the universe to its supposed development through natural laws. It was later argued—by, among others, Immanuel Kant—that this happened in a regular fashion as suns and planets were formed from gaseous nebulae. Biological evolutionary ideas began to appear towards the end of the eighteenth century. A prominent exponent in England was the physician and naturalist Erasmus Darwin, grandfather of Charles Darwin; in France a little later the chief advocate of the idea was the biologist Jean Baptiste de Lamarck.

The evidence offered for evolution (then more generally called *transmutation*) tended to be anecdotal. A major reason why few endorsed the idea with enthusiasm was that it was seen to be a reflection of the ideology of progress—upward change in the human social world, and upward change in the history of life, from "monad" to "man." Critics, like the father of comparative anatomy, the French biologist Georges Cuvier, found the idea religiously offensive less because it clashed with literal interpretations of the Bible than because of its underlying philosophy of progress. Such a world picture, in which humans can make the difference unaided, was at odds with the Christian notion of providence, where all depends on God's grace. Although by the mid nineteenth century religious worries were still much in evidence, Charles Darwin met this challenge head on in the *Origin of Species* (1859), the groundbreaking work in which he introduced his theory. Darwin was not the first to argue for the fact of evolution, but by marshaling so much evidence from paleontology, embryology, geographical distributions, and more, he made the fact of evolution empirically plausible and no longer reliant on an underlying social philosophy for acceptance.

The path of evolution

The path of evolution, or *phylogeny,* is simply the history of the past as given in the fossil record and as can be discerned indirectly from anatomical and embryological causes and, increasingly, molecular evidence. Thanks to various sophisticated methods of dating, researchers can say that the universe itself is (since the Big Bang) about fifteen billion years old, that the Earth is about 4.5 billion years old, and that life first appeared on the planet about 3.75 billion years ago. Complex life began with the Cambrian explosion about six hundred million years ago; the Age of Mammals began about sixty-five million years ago (although the first mammals go back two hundred million years); the first known ancestors of humans are about four million years old (upright but with ape-sized brains); and, depending on how one measures things, the modern human species *Homo sapiens* is between five hundred thousand and a million years old.

Traditionally, life is pictured as a tree with contemporary organisms at the ends of the upper branches. However, Lamarck and some other early evolutionists thought that life developed upwards in separate but parallel lines, with variations laid over these. Alternatively, some researcher believe that viruses may carry genes from one line to other, very different, lines, so perhaps a better picture is that of a net. Paradoxically, the main outlines of the history of life were worked out in the first part of the nineteenth century, primarily by those who did not subscribe to evolution, and only later was the process of life given an evolutionary interpretation.

The theory or mechanism of evolution

The theory or mechanism of evolution has garnered many hypotheses. Notorious before Darwin was Lamarck's idea of the inheritance of acquired characteristics, which had not originated with him; Erasmus Darwin had accepted it, as did Charles Darwin much later. In the *Origin of Species,* Darwin described the mechanism that is generally accepted as the chief force for change: *natural selection.* More organisms are born than can survive and reproduce, leading to a struggle for survival and, more importantly, reproduction. Given naturally occurring variation, and the fact that those that survive will tend on average to be different from those that do not, there will be a *differential reproduction,* natural selection. In time this leads to full-blown evolution, and evolution of a particular kind, for selection produces organisms with *adaptations.* The eye and the hand come naturally as a result of Darwin's causal process.

Conclusion

In the years subsequent to the publication of Darwin's *Origin,* there have been a multitude of putative alternatives to Darwinian selection, including *orthogenesis* (a life force driving things), *mutationism* (major one-step changes), *genetic drift* (randomness), and *molecular drive* (DNA has its own built-in ways of change); none has established itself as a full and genuine rival to natural selection. This is not to say that all controversy is therefore quelled. Apart from the question of whether selection can be applied profitably to such issues as the origin of life, there are also questions about the form that life's history will take given selection as the main mechanism of change. Will it be smooth and gradual (*phyletic gradualism*), as supposed by Darwin and his followers, or will it be jerky and abrupt (*punctuated equilibria*), as supposed by some leading paleontologists, notably Stephen Jay Gould? Controversy about these issues, however, should not be taken as controversy about other matters. The fact of evolution is firmly established, the main outlines of the path of evolution have been worked out and details are being filled in (for example, that birds are descended from dinosaurs), and selection is taken to be the major mechanism of change even though there are debates about its applicability and its precise results and consequences.

Evolution as fact, path, and theory is a thriving part of the biological sciences, and it is also seen to have extensions and implications for thinking about many other parts of human experience. Social scientists are increasingly turning to evolutionary ideas to flesh out their understanding of human nature and society; philosophers have (after many hesitations) begun to see how evolution, selection even, can profitably deepen their understandings of epistemology (theory of knowledge) and ethics (theory of morality); novelists and poets use evolutionary themes to illuminate aspects of human understanding and motivation; linguists turn to Darwinism for help in grasping the developments of languages; and so it is in many other subjects and disciplines. Although there is still much opposition to evolutionary ideas on various religious fronts, there is realization by theologians and historians that the old story of the warfare between science and religion was much overblown, and many see evolution as an aid to faith and understanding rather than a hindrance.

See also DARWIN, CHARLES; EVOLUTIONARY EPISTEMOLOGY; EVOLUTIONARY ETHICS; LAMARCKISM; SELECTION, LEVELS OF; SOCIOBIOLOGY

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MICHAEL RUSE

EVOLUTIONARY ALGORITHMS

Evolutionary algorithm is a term that describes the use of evolutionary models and methods in the design of computer programs, robots, and artificial life. Incorporating evolutionary strategies into computer programs was first proposed by Lawrence Fogel in the early 1960s. This work was significantly advanced by the invention of genetic algorithms by John Holland in 1975. Widespread interest in evolutionary computing, however, did not develop until the late 1980s and early 1990s, with the first conference on evolutionary computing being held in 1992 in La Jolla, California. Evolutionary computing methods are now used in a wide range of civilian and military applications, and the techniques of evolutionary computing are seen by some to be the future of both computer programming generally and artificial intelligence specifically.

Traditional computer programs rely on a sequence of precise instructions (algorithms) that commands a computer or robot to perform specific actions. Evolutionary computing mimics biological evolution by developing a program that considers a set of possible solutions for a given problem, evaluates the solutions according to fitness criteria, mutates the solutions according to set rules, and then repeats the sequence until a sufficiently optimal solution is found. Programs that utilize genetic algorithms attempt to more closely mimic neo-Darwinian evolution by providing each solution with a chromosome. Solutions then "mate" with one another, creating a new generation of solutions. The most fit solutions are selected out, and are allowed to mate and mutate further, until an optimal solution is found.

Much of the interest in evolutionary algorithms is due to their success in solving problems that are computationally difficult or impossible by traditional means. The most famous of these is the "traveling salesman problem," which attempts to find the shortest path between any two destinations. While the individual task may sound trivial, it represents a class of problems that are mathematically quite important. The techniques of evolutionary computing have also been used in the development of artificial life, creating virtual organisms that feed, reproduce, and compete within a computer-generated environment. In 2000, Hod Lipson and Jordan Pollack applied evolutionary computing to robotics, developing a program that creates mobile robots through a process of mutation and selection.

These and similar successes have led some to conclude that evolutionary algorithms provide basic insights into evolutionary theory, confirming basic neo-Darwinian principles of natural selection. Richard Dawkins's distribution of his biomorphs program along with his book *The Blind Watchmaker* (1986) is an early instance of this sort of claim in a popular science work. Critics of evolution, such as William Dembski, however, have argued that evolutionary computing does not provide evidence for neo-Darwinism because the algorithms must first be designed by a human being.

Evolutionary algorithms are also held to provide insight into the nature of intelligence itself. Thinkers as diverse as Daniel Dennett, Karl Popper, and Michael Ruse have argued for a similarity between evolution by natural selection and basic cognitive tasks, and evolutionary computing began, in part, to solve issues related to the development of artificial intelligence.

See also AUTOMATA, CELLULAR; COMPLEXITY

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GREGORY R. PETERSON

EVOLUTIONARY COMPUTING

See EVOLUTIONARY ALGORITHMS

EVOLUTIONARY EPISTEMOLOGY

Evolutionary epistemology widens the scope of traditional epistemology by inclusion of considerations of the evolutionary origins of human cognitive capacity. The roots of evolutionary epistemology extend back to Charles Darwin's idea of natural selection, set forth in 1859, and to subsequent vivid discussions of the evolutionary origin of human rational capacity put forth by Darwin's followers. Contemporary evolutionary epistemology is based on the work of three seminal thinkers: Karl Popper, Konrad Lorenz, and Jean Piaget. Evolutionary epistemology is an interdisciplinary and constructive theory that aims to unite philosophical views on human knowledge with theories of both human origin and life in general.

Program

Evolutionary epistemology suggests that human cognitive capacity is the result of evolutionary development and can be understood only with the help of evolutionary theories that describe the development of this capacity. In fact, evolution itself is understood as a cognition-gaining process: Thus, Gerhard Vollmer suggests that "knowledge is an adequate reconstruction of the outside structures in the subject, and cognition is the process leading to knowledge" (p. 70). Consequently, knowledge can be seen as a tiered phenomenon: On each level, only those responses "fitting" their environment are retained for the future. On the *genetic level* of knowledge, basic information about the environment is captured in the physical construction of the body by natural selection of those characteristics fitting the environment. A second level is *preconscious cognition,* which includes reflex-based responses to sudden environmental changes. The third level is that of *rational knowledge,* in which a person's reaction to the environment is guided by rational judgment.

Lorenz used these principles of evolutionary epistemology to critique the Kantian concept of *a priori*: If cognition is a capacity acquired through the evolutionary process, it is, to any given individual, *ontogenetically a priori.* However, the origins of human cognitive capacity and knowledge as products of evolutionary processes reach back to nonhuman ancestors, and in that sense should be viewed as *phylogenetically a posteriori.* Thus, human cognitive functions are shaped by the environment that is known. Furthermore, human knowledge, including its a priori component, is provisional: It is neither infallible nor arbitrary. Its success lies in examining the long-term "fit" between the world and physical/mental appropriations to the world, as found in neural and mental structures of the knowing subject. Therefore, evolutionary epistemology subscribes to *hypothetical realism,* a special type of realism which claims that human knowledge of the external world is a well-founded and reliable hypothesis about external reality. While it is possible to see the parallel between biological evolution and conceptual evolution (the later being the evolution of ideas) as literal, the real strength of evolutionary epistemology is in applying it analogously to all processes involved in the acquisition of knowledge.

Such an extension was established by Karl Popper. His philosophy transforms the principle of elimination of "unfit hypotheses" about reality (occurring on the planet since biological evolution began) to an abstract level of scientific hypotheses. The resulting system claims to provide the basis for the objectivity of knowledge: While social circumstances influence the expressions of beliefs, the beliefs themselves are not caused by these circumstances alone but have an objective component.

These principles of selective retention of fitting structures, both physical and mental, lead to a very high efficiency in the entire cognition-gaining process: Only successful variations are retained, thereby becoming a basis for future selective processes. Cases where blind chance seemingly operates in evolutionary processes are in the system of *nested hierarchies,* preselected by past successes. These principles are applicable to all levels and forms of knowledge-gaining processes, but at the same time do not allow for the reduction of culture to biology. What is emphasized is the parallel to knowledge-gaining processes in biological and cultural evolution.

Consequently, evolutionary epistemology is capable of examining the formal structure of any kind of human knowledge, including areas traditionally barred from scientific study, such as religions. Donald T. Campbell suggests that, from a scientific point of view, human sociocultural inheritance is as reliable as biological inheritance.

Impact on science and religion

Campbell's proposal was theologically appropriated by Ralph Wendell Burhoe, who attempted to employ the ideas of evolutionary epistemology to relate scientific and religious thought. For Burhoe there is, in principle, no difference between the discernment of the validity of religious beliefs and the discernment of the validity of scientific claims: Knowledge in both areas is acquired through methods described by evolutionary epistemology. Therefore, natural sciences should no longer claim methodological and epistemic superiority over religion. Burhoe, however, went even further, stating that "religious belief systems characteristically involve man's relation or adaptation to some ultimate realities" (p. 30). Implicitly, such a claim points to the reality of God: If one presupposes that selection processes take place through confrontation with reality, and result in the acquisition of information about selecting reality, then "adaptation to ultimate reality" can be translated into "acquisition of knowledge about an independently existing God."

Theologically, evolutionary epistemology represents an important new methodological tool. While it does not fall into the trap of natural theology by attempting to argue about God on the basis of knowledge of the world, it advocates that the acquisition of religious knowledge follows the same principles as the acquisition of knowledge of the material world. Since the reliability of cognitive claims is based on the methods used to derive them, religious claims are no longer epistemically inferior to any other kind of knowledge.

Critiques

Critics of evolutionary epistemology argue that survival and reproduction are the only ends of evolutionary development, and that selected knowledge is not true information about reality but merely a situationally successful resolution of a given situation. The success of such a solution is understood by these critics without relating it to reality. While it is correct that knowledge-gaining processes described by evolutionary epistemology do not lead to true knowledge but rather to truly reliable hypotheses, this charge is based on the faulty presupposition that long-term solutions based on evolutionary selection could result from false assessments of external reality.

Other critics lament that evolutionary principles are inherently egoistic and, consequently, that the realm of ethics and religion can not be described by evolutionary epistemology. This criticism is, again, based on the faulty presupposition that evolution's primary value is mere survival. Evolutionary epistemology, however, redefines evolution as a knowledge-gaining process that makes the outcome of the evolutionary process dependent upon what has been retained and what is learned.

Recently, the findings of evolutionary epistemology have been confirmed by new trends in several disciplines. The most promising discipline is evolutionary psychology, along with new studies in human development and paleontology. While the slowly emerging picture of human cognitive ability seems to be inviting theology as a dialogue partner, advances made during the last two decades of the twentieth century suggest that theology will benefit greatly from including evolutionary epistemology among its methodological tools.

See also EPISTEMOLOGY; EVOLUTIONARY ETHICS; EVOLUTIONARY PSYCHOLOGY; HYPOTHETICAL REALISM

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TOMAS HANCIL

EVOLUTIONARY ETHICS

The term *evolutionary ethics* refers to three different fields of inquiry that share a concern for the relationship between ethics and evolutionary theory. First is the question of how the human capacity for ethics could have arisen through natural selection—the evolution of ethics. Second is the issue of how the process of evolution appears to exacerbate the problem of natural evil and theodicy—the ethics of evolution. Third is the question of what implications Darwinian theory has for ethical understanding and whether it is possible to derive an ethical system from evolutionary biology—ethics from evolution.

Evolution of ethics

Charles Darwin (1809–1882) speculated on, but did not resolve, the question of how ostensibly sacrificial social cooperation, and especially human morality, could be established by natural selection, which entails the preferential transmission of biological characteristics that confer reproductive advantage to their possessor. In the 1970s, breakthroughs in the application of Darwinian theory to animal social behavior by the emerging discipline of sociobiology shed light on this problem through the notion of reciprocal altruism, suggesting that organisms sacrifice for others in proportion to the likelihood of a compensatory return. Some species, such as social insects, achieve high cooperation in large group sizes, at the cost of rigid and therefore predictable behaviors. Other species, such as nonhuman primates, can achieve high cooperation with significant behavioral flexibility, within the constraints of small group sizes where relational history can be monitored. Human morality is widely viewed as facilitating the unique capacity for significant cooperation in the context of both high behavioral flexibility and large group sizes. Morality not only urges us, but in a sense enables us, to be kind to strangers.

Far from settling the biological origin of ethics however, these notions have stimulated vigorous debate. One controversy is over whether ethical behavior can be understood as invariably benefiting the actor's or others' reproduction; that is, is morality an individual or group level adaptation? Extending the influential ideas of George Williams and Richard Dawkins, in his seminal work, *The Biology of Moral Systems* (1987), Richard Alexander maintains that moral acts, even those not directly paid back, benefit the individual by indirect reciprocity or reputational enhancement. We are as morally good as it takes to enhance our social standing, and conscience is a reputation alarm that goes off when we are cheating in a way likely to get caught. Conversely, David Wilson and Christopher Boehm argue that human evolution has established the capacity for moral acts that entail uncompensated personal sacrifice and benefit the group relative to competing groups.

Another debate waged both within and outside evolutionary biology involves the question of whether morality is adequately explainable by natural selection at all. One view considers morality not as an evolutionary adaptation but as a byproduct of other biologically adaptive capacities, such as intelligence and the capacity for group cooperation. Another position, coevolutionary or hierarchy theory, views moral systems and other higher cognitive functions as influenced by nongenetic evolutionary processes that are not constrained by natural selection. Proponents reject genetic reductionism and affirm both genuine moral freedom and radical outgroup sacrifice. Scientific and theological critics maintain it is dualistic, even Gnostic, in viewing beneficence as a nonmaterial imposition on an innately selfish human biology. These disputes mirror longstanding theological differences over embodiment and the work of grace.

Ethics of evolution

In his 1893 Romanes lectures, Thomas Henry Huxley (1825–1895) reflected on the relationship between natural evil and evolutionary ethics. While natural evil is considered by many religious and wisdom traditions, evolutionary theory has been viewed as intensifying the quandary in three ways. First, it extends the temporal and biological scope of suffering and death. They become primal features rather than post-hoc additions to creation; moreover, death ravages not only individuals but also entire species, previously considered fixed in divine providence. Second, the role of natural evil changes from an ancillary intrusion upon God's mode of creation to the central driving force of the process itself. The very engines of creation seem to be the competition and selective carnage of natural selection. Third, not just the process but the products of natural selection raise ethical questions: In many representations, the Darwinian picture of the world is colored by dominant hues of self-interest and an utter absence of natural beneficence. A century after Huxley, George Williams argued that evolutionary theory and sociobiology paint an even bleaker picture.

Some theodicies respond to this view of the world by affirming eschatological extrapolations of evolutionary progress. Others criticize the picture itself. Darwin maintained death was most often swift, and selection favored pleasure over pain in behavioral motivation. Moreover, natural selection is actually not driven by selective mortality, but by differential fecundity. Finally, symbiotic cooperation may be as important in evolution as competitive displacement. Whether the most apt metaphor for evolution is "nature is red in tooth and claw" or "exuberant in youth and bough" is an object of ongoing debate, and the controversy itself has significant theological implications.

Ethics from evolution

The relationship of evolution to ethical theory is debated along two main lines. First is the metaethical question of whether a naturalistic origin of ethics makes divine command theory, or any form of moral realism, untenable. Michael Ruse argues that evolution entails moral relativism because what seems right is merely what happens to work in conferring reproductive success. Conversely, Nancy Murphy and some process thinkers argue that the universe operates in such a way that what works actually tends toward the right and good.

Another controversy involves the normative ethical question of whether evolution can inform moral understanding. Advocates of this view, such as Ruse and natural law proponent Larry Arnhart, argue evolution can contribute, first, by elucidating what is biologically impossible in light of natural selection and therefore errant to command. Ruse thus claims the New Testament's radical love command is biologically perverse. Second, if we understand the evolutionary function of human behavioral traits, we can discern what is most likely to facilitate or subvert fulfillment, and therefore inform ethical judgments. Critics argue that limiting our ethical vision to what conforms with prevailing views of the natural dismisses the work of grace in redeeming, or moral imagination in reforming, nature. Especially since the evolutionarily natural may not be so good, we are cautioned to avoid the naturalistic fallacy of attempting to infer a moral *ought* from a brute *is*. Furthermore, evolution-based ethics cannot adjudicate between conflicting impulses: If the function of all behavior is reproductive advantage, then slavery is not ethically preferable to benevolence, assuming both sustainably maximize fitness. Huxley's *Evolution and Ethics* (1894) made these criticisms of Herbert Spencer's (1820–1903) evolutionary ethics, and the debates continue to this day.

See also ECOLOGY, ETHICS OF; EVOLUTION, BIOCULTURAL; EVOLUTIONARY EPISTEMOLOGY; NATURE; NATURE VERSUS NURTURE; SOCIOBIOLOGY

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EVOLUTIONARY PSYCHOLOGY

Evolutionary psychology assumes that operating beneath the surface of historical and cultural variability, the human mind is a system of functionally specialized, developmentally constructed neural information processors that were naturally selected because they solved particular adaptive problems faced during the evolution of the hunter-gatherer ancestors of human beings. Evolutionary psychology assumes a computational theory of mind rooted in the information processing revolution of the 1960s. It also draws on insights from the sociobiology of the 1970s, which describes how “selfish” genes, in benefiting their own replication and that of copies amongst kin (William D. Hamilton’s “inclusive fitness”), direct the generation of organic structures, including those that may incidentally benefit the organism. With the natural selection of species-wide characteristics, evolutionary psychology considers sexual selection, including the effects of parental investment, and has made empirical contributions to understanding the proximal mechanisms behind mate choice, cheater detection, and language acquisition.

Evolutionary psychology avoids a collapse to genetic determinism through its attention to development and environment, including social interaction and coevolutionary systems. Nevertheless, any computational theory of mind may ultimately be inadequate, and there are questions about the empirical robustness of its findings.

See also EVOLUTIONARY EPISTEMOLOGY; EVOLUTIONARY ETHICS; SELFISH GENE; SOCIOBIOLOGY

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EVOLUTION, BIOCULTURAL

From its beginnings in the eighteenth century, evolution—the idea that organisms are descended through a gradual development, ruled by natural law, from original, simple, primitive forms—was intermingled with thoughts of culture. In fact, it is difficult to distinguish the two, since early evolutionists tended to start with a theory about culture, generalize to the biological world, then use biology to support beliefs about culture. In particular, especially as represented in the writings of the English physician and naturalist Erasmus Darwin (1731–1802, the grandfather of Charles) and the French biologist Jean Baptiste de Lamarck (1744–1829), one encounters ideas about social and cultural progress. Darwin, Lamarck, and others promoted the belief that knowledge and society can be improved through unaided human effort; such ideas were read into the animal and plant realm (monad to man, to use the popular phrase), then read back into the human realm to support ideas of social and cultural progress.

Three problem areas

The study of biocultural evolution presents three problematic issues. First, there is the fact of evolution and its causes as applied to the organic world generally. The big question concerning evolution is the “mechanism,” and the major debate is over the adequacy and extent of the causal process proposed by Charles Darwin (1809–1882) in his *Origin of Species* in 1859. Does one accept, and to what extent does one accept, the mechanism of natural selection, according to which more organisms are born than can survive and reproduce, producing a struggle that results in a differential reproduction of the fittest, which leads to change in the direction of adaptation? Should the mechanism of selection be limited or replaced? The consensus among practicing biologists is that selection is extremely significant, and, although there is disagreement, most would say that selection is by far the most important mechanism.

A second problem concerns the application of evolutionary theory to humans. Few scientists today would dispute that human beings evolved, but again there is debate about the extent to which selection is significant, with nearly all agreeing that it has had some significant role. The hand and the eye, for example, are adaptations produced by selection. How much and how far selection has affected and shaped human behavior and thought, however, is still a matter of (sometimes bitter) debate. Some researchers, particularly those called human sociobiologists or evolutionary psychologists, grant selection a major role in determining human behavior and thought. Others, in particular cultural anthropologists and those with ideologies opposed to certain aspects of biology (a group that often includes feminists, Marxists, and postmodernists), tend to downplay the importance of biology in shaping behavior. Most concede to biology some role, but even here there is dispute. For example, male and female (human) physical differences are obviously a function of biology; whether male and female psychological and social differences are a function of biology is less clear.

A third problem is the question of cultural evolution or change. There is, of course, continuity in science or religion. Albert Einstein (1879–1955) did not just appear, he arose out of a physics tradition that dates back at least to Isaac Newton (1642–1727). Christianity did not just appear but goes back to Judaism, with introgressions of a greater or lesser extent from Greek philosophy. The question is whether one can develop a theory of such change, and if so what kind of theory. In particular, do biological theories help one to understand cultural change? Moreover, does natural selection offer a causal insight into the way and reasons that culture changes? From Newton to Einstein, from Moses to Paul, are the processes that rule such changes the same process that ruled the evolution of the reptile to the bird, or the monkey to the human being?

Assuming acceptance of the first point (evolution in general) and of the second point (evolution of humans), then the third point (cultural evolution) becomes the critical question. If one accepts the possibility of cultural evolution of some kind—and it is hard not to, at least in a general sense—then does one start with the second point (evolution of humans) and work to the third point (cultural evolution)? Or does one jump straight to the third point (cultural evolution)? In other words, is cultural evolution autonomous in some sense, sitting at the summit of the biological sciences (as many cultural anthropologists would argue), or does cultural evolution arise as a consequence of human biological evolution? And returning to the issue of causes, what role does selection play in this process, and how does it affect one's answer?

Nineteenth-century discussions

It is fair to say that Erasmus Darwin and Lamarck were evolutionists, and they applied evolutionary theory to humans, although neither was aware of natural selection, though in Erasmus Darwin's writings there are hints of sexual selection, the competition for mates. Darwin and Lamarck were not, however, sufficiently sophisticated in their thinking to address cultural evolution; it is probably best to say that they thought of cultural evolution as autonomous, but fueled by the same processes as biological evolution, chiefly the inheritance of acquired characteristics. Although such a view is now known as *Lamarckism,* it also appeared in writings by Erasmus Darwin. People often note that the Lamarckian evolutionary mechanism of the inheritance of acquired characteristics seems cultural. They are right. It was taken from culture, so it is not surprising that it can be read back to culture. Much the same can be said of later pre-Darwinian evolutionists. However, by the mid-1850s, cultural evolution was definitely being seen as autonomous, although biology and culture were considered ultimately part of the same process, in which things moved in Lamarckian fashion from simple to complex, from homogeneous to heterogeneous. As the philosopher Herbert Spencer (1820–1903) remarked:

> Now we propose in the first place to show, that this law of organic progress is the law of all progress. Whether it be in the development of the Earth, in the development of Life upon its surface, in the development of Society, of Government, of Manufactures, of Commerce, of Language, Literature, Science, Art, this same evolution of

> the simple into the complex, through successive differentiations, hold throughout. From the earliest traceable cosmical changes down to the latest results of civilization, we shall find that the transformation of the homogeneous into the heterogeneous, is that in which Progress essentially consists. (Spencer 1857)

Spencer was not much interested in selection, even though the idea occurred to him independently of Darwin. Others took a similar approach to Spencer but included selection in their theories. Thomas Henry Huxley (1825–1895) was probably the first to argue that there is a struggle for existence among ideas, and the fittest win. Einstein triumphed over Newton because Einstein's ideas are in some way better than Newton's. For Huxley, who invented the term *agnostic,* Darwin beat out Christianity because Darwin's ideas were better than Christianity.

What about Darwin himself? He certainly wrote about humans and was interested in culture. At times he sounds as if he believed culture to be reasonably autonomous, but one senses that he was not convinced of this. In the *Descent of Man* (1871) he is more inclined to start with human evolution and then work outward and backward to culture. Morality, for example, has biological value because it helps keep the tribe together. Thus, there is evolution toward a moral sense, which then feeds back to biology because creatures that are more moral are also more biologically successful. Similarly, social practices, particularly social sexual practices, start with biology, get encoded into culture, and then feed back into biology. Even capitalism can be conceived in Darwinian terms as something that aids evolution and hence is cherished and adaptive.

In general, it seems fair to say that for the century after Darwin, the biology to culture approach did not thrive. Thanks to the popularity of Spencer and his followers, as well as to the rise of the social sciences and to the difficulty of understanding the biology of behavior and thought, cultural evolution was considered to be a process in its own right. The philosopher William James (1842–1910), for instance, takes a Darwinian approach in his *Principles of Psychology* (1890), although in the more philosophical *Pragmatism* (1907), he treats culture as more autonomous. And although Spencer is no longer highly regarded as a thinker, and although few would subscribe to Spencer's beliefs about the nature and course of evolution, many still treat culture as Spencer did, as autonomous but with causes that are analogous to biology. In fact, many follow in the steps of Huxley in seeing selection as key to understanding cultural, particularly scientific, change.

Twentieth-century discussion

Such an approach is often called *evolutionary epistemology.* Its best-known proponent was the philosopher Karl Popper (1902–1994), who combined an evolutionary approach with his own criterion for distinguishing science from nonscience: *falsifiabilty.* One starts with a problem, say a discovery that seems not to fit with existing theory. One then proposes an idea or hypothesis intended to solve the problem, or more likely, one proposes a number of ideas or hypotheses. One then subjects the ideas to rigorous testing, choosing the idea that survives or solves the problem best. All the others must be rejected, including ideas or hypotheses one may have held earlier. In effect, a change has occurred through a process analogous to natural selection. One then continues until another problem arises.

Those sympathetic to Popper's approach include Stephen Toulmin and David Hull, the latter having applied the approach to the eclipse of traditional evolutionary methods of biological classification with the new *cladistic* approach. This is a method of classification that uses only shared characteristics as the method of classification, aiming to represent lines of descent and nothing else. Richard Dawkins's theory about units of belief called *memes,* which are analogous to genes, also fits here. Dawkins believes that memes invade brains (rather like viruses) and then multiply and succeed in a Darwinian fashion, inasmuch as they have good cultural adaptations. Religion, in particular, is something that Dawkins thinks has no objective truth but nevertheless succeeds because it has good adaptations. It exploits people's need to belong and their need for comforting answers about life after death and other matters.

Thomas Kuhn (1922–1996), who is usually regarded as representing an approach to the understanding of science diametrically opposed to that of Popper, also liked to think of his "paradigm" theory of science as evolutionary. A paradigm is proposed, and another is rejected, in Darwinian fashion. Popper was a realist, committed to the idea of an independent, real world, unlike Kuhn, for whom reality, inasmuch as it exists, is a function of human perception. The important question of progress remains. Is science progressive? Does it progress toward an understanding of the real world, or is it simply going nowhere and just subject to fashion? Popper certainly thought of his epistemology as progressive. Kuhn, who was more ambiguous, saw progress in a Darwinian sense, in which certain ideas are better than rivals, rather than in an absolute sense, in which some ideas are better on some independent scale. Dawkins would probably take an even more relativistic approach than Kuhn.

With the rise of human sociobiology (or evolutionary psychology) there is an increasing interest in the Darwinian approach to culture. This interest results, in part, from dissatisfaction with the alternative approach. But if culture is Darwinian, then how can one explain the fact that biological mutations are random (in the sense of undirected), whereas cultural mutations are apparently nonrandom? The sociobiologist Edward O. Wilson, working with physicist Charles Lumsden, argues that culture is founded on various rules of thought, which he calls *epigenetic rules,* or which might be called "innate dispositions." As the philosopher W. V. O. Quine (1908–2000) argued, mathematical rules or the laws of logic may be ingrained in human biology because protohumans who thought logically were more likely to survive than those who did not. So culture, which can then elaborate in ways unknown to biology, nevertheless has its base in biology. It is not so much that Einstein's ideas beat out Newton's in a struggle for existence, but that both theories are based on rules that are rooted in biology. The success of one over the other is simply an observation, and not really biological at all.

A number of scholars, including Wilson and Michael Ruse, have applied this approach to morality, arguing that supreme imperatives, like the Christian love commandment, are held because those human ancestors who took them seriously were more successful than those who did not. Such an approach does not preclude cultural developments alongside those of biology. For example, whether it is ever obligatory to tell lies—as to a child dying of cancer—is not something determined by natural selection, although the tendency to be kind to such children certainly is.

What of religion in all of this? Wilson certainly thinks that religion is promoted by biology inasmuch as it reinforces morality and promotes group harmony and cohesion. Like Dawkins, however, he is something of a nonrealist on these matters and thinks that religious beliefs are not objectively true. Indeed, he would replace Christianity with a better myth (his word), namely Darwinian materialism. Others who take this approach, including the ethologist Konrad Lorenz (1903–1989), incline to a more realist approach. Whether or not they themselves accept religious beliefs as true, they would allow the possibility that they could be found true.

There are, in fact, scholars who apply biology to an understanding of religion. They do not treat religion as culturally autonomous but as a system of beliefs that can feed back into biology and vice versa. In other words, they would probably not regard such beliefs as innate but as one of a cluster of characteristics that have biological, and not just cultural, adaptive advantage, and hence serve as an aid to the possessors. Religious beliefs maintain a kind of halfway position between the two extremes described above (culture as autonomous and culture as an epiphenomenon of biology). Primatologist Vernon Reynolds and R. Tanner, a student of religion, have argued that different religions speak to different biologically adaptive needs. Using standard biological theory, which distinguishes between adaptations that are needed when resources are not stable or predictable and adaptations that are needed when resources are stable and predictable, they argue that religions reflect these conditions. Their theory predicts that organisms will tend to have numerous offspring that require minimal parental care during periods of instability or unpredictability, and few offspring requiring much care during periods of stability. Reynolds and Tanner argue that in a place like Great Britain, which has stable resources, one finds (expectedly) a religion like Anglicanism that stresses restraint and care, whereas in a place like Ireland, where resources fluctuate, one finds Catholicism with its exhortation to have many children. Other practices discussed by Reynolds and Tanner include food rules and prohibitions (as in Judaism), attitudes toward women, and much more.

Even though it is now nearly 150 years since the *Origin of Species* appeared (and two hundred since the start of evolutionary thinking), it is probably too early to say that a generally acceptable biocultural theory has been formulated. There are, however, many stimulating, if controversial, ideas, which promise to cast light on culture, including science and religion, and the relationship between them.

See also CULTURE, ORIGINS OF; EVOLUTION, BIOLOGICAL; EVOLUTIONARY EPISTEMOLOGY; EVOLUTIONARY ETHICS; EVOLUTIONARY PSYCHOLOGY; HUMAN NATURE, PHYSICAL ASPECTS; SOCIOBIOLOGY

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EVOLUTION, BIOLOGICAL

Biological evolution encompasses three issues: (1) the fact of evolution; that is, that organisms are related by common descent with modification; (2) evolutionary history; that is, when lineages split from one another and the changes that occur in each lineage; and (3) the mechanisms or processes by which evolutionary change occurs.

The fact of evolution is the most fundamental issue and the one established with utmost certainty. During the nineteenth century, Charles Darwin (1809–1882) gathered much evidence in its support, but the evidence has accumulated continuously ever since, derived from all biological disciplines. The evolutionary origin of organisms is today a scientific conclusion established with the kind of certainty attributable to such scientific concepts as the roundness of the Earth, the motions of the planets, and the molecular composition of matter. This degree of certainty beyond reasonable doubt is what is implied when biologists say that evolution is a *fact*; the evolutionary origin of organisms is accepted by virtually every biologist.

The theory of evolution seeks to ascertain the evolutionary relationships between particular organisms and the events of evolutionary history (the second issue above). Many conclusions of evolutionary history are well established; for example, that the chimpanzee and gorilla are more closely related to humans than is any of those three species to the baboon or other monkeys. Other matters are less certain and still others—such as precisely when life originated on earth or when multicellular animals, plants, and fungi first appeared—remain largely unresolved. This entry will not review the history of evolution, but rather focus on the processes of evolutionary change (the third issue above), after a brief review of the evidence for the fact of evolution.

The evidence for common descent with modification

Evidence that organisms are related by common descent with modification has been obtained by paleontology, comparative anatomy, biogeography, embryology, biochemistry, molecular genetics, and other biological disciplines. The idea first emerged from observations of systematic changes in the succession of fossil remains found in a sequence of layered rocks. Such layers have a cumulative thickness of tens of kilometers that represent at least 3.5 billion years of geological time. The general sequence of fossils from bottom upward in layered rocks had been recognized before Darwin proposed that the succession of biological forms strongly implied evolution. The farther back into the past one looked, the less the fossils resembled recent forms, the more the various lineages merged, and the broader the implications of a common ancestry.

Although gaps in the paleontological record remain, many have been filled by the researches of paleontologists since Darwin’s time. Millions of fossil organisms found in well-dated rock sequences represent a succession of forms through time and manifest many evolutionary transitions.

Microbial life of the simplest type (i.e., procaryotes, which are cells whose nuclear matter is not bound by a nuclear membrane) was already in existence more than three billion years ago. The oldest evidence of more complex organisms (i.e., eukaryotic cells with a true nucleus) has been discovered in flinty rocks approximately 1.4 billion years old. More advanced forms like algae, fungi, higher plants, and animals have been found only in younger geological strata. The following list presents the order in which increasingly complex forms of life appeared:

Life form	Millions of years since first known appearance (approximate)
Microbial (procaryotic cells)	3,500
Complex (eukaryotic cells)	1,400
Multicellular animals	670
Shell-bearing animals	540
Vertebrates (simple fishes)	490
Amphibians	350
Reptiles	310
Mammals	200
Nonhuman primates	60
Earliest apes	25
Australopithecine ancestors	5
Homo sapiens (modern humans)	0.15 (150,000 years)

SOURCE: Steering Committee on Science and Creationism, National Academy of Sciences. *Science and Creationism: A View from the National Academy of Sciences,* Second Edition. National Academy Press: Washington, DC, 1999.

Forms of life by year of origin.

The sequence of observed forms and the fact that all (except the procaryotes) are constructed from the same basic cellular type strongly imply that all these major categories of life (including plants, algae, and fungi) have a common ancestry in the first eukaryotic cell. Moreover, there have been so many discoveries of intermediate forms between fish and amphibians, between amphibians and reptiles, between reptiles and mammals that it is often difficult to identify categorically along the line when the transition occurs from one to another particular genus or from one to another particular species. Nearly all fossils can be regarded as intermediates in some sense; they are life forms that come between ancestral forms that preceded them and those that followed.

Inferences about common descent derived from paleontology have been reinforced by comparative anatomy. The skeletons of humans, dogs, whales, and bats are strikingly similar, despite the different ways of life led by these animals and the diversity of environments in which they have flourished. The correspondence, bone by bone, can be observed in every part of the body, including the limbs: Yet a person writes, a dog runs, a whale swims, and a bat flies with structures built of the same bones. Such structures, called *homologous,* are best explained by common descent. Comparative anatomists investigate such homologies, not only in bone structure but also in other parts of the body as well, working out relationships from degrees of similarity.

The mammalian ear and jaw offer an example in which paleontology and comparative anatomy combine to show common ancestry through transitional stages. The lower jaws of mammals contain only one bone, whereas those of reptiles have several. The other bones in the reptile jaw are homologous with bones now found in the mammalian ear. What function could these bones have had during intermediate stages? Paleontologists have discovered intermediate forms of mammal-like reptiles (*Therapsida*) with a double jaw joint—one composed of the bones that persist in mammalian jaws, the other consisting of bones that eventually became the hammer and anvil of the mammalian ear. Similar examples are numerous.

Biogeography also has contributed evidence for common descent. The diversity of life is stupendous. Approximately 250,000 species of living plants, 100,000 species of fungi, and 1.5 million species of animals and microorganisms have been described and named, and the census is far from complete. Some species, such as human beings and our companion the dog, can live under a wide range of environmental conditions. Others are amazingly specialized. One species of the fungus *Laboulbenia* grows exclusively on the rear portion of the covering wings of a single species of beetle (*Aphaenops cronei*) found only in some caves of southern France. The larvae of the fly *Drosophila carcinophila* can develop only in specialized grooves beneath the flaps of the third pair of oral appendages of the land crab *Gecarcinus ruricola,* which is found only on certain Caribbean islands.

How can one make intelligible the colossal diversity of living beings and the existence of such extraordinary, seemingly whimsical creatures as *Laboulbenia, Drosophila carcinophila,* and others? Why are island groups like the Galápagos inhabited by forms similar to those on the nearest mainland but belonging to different species? Why is the indigenous life so different on different continents? The explanation is that biological diversity results from an evolutionary process whereby the descendants of local or migrant predecessors became adapted to diverse environments. For example, approximately two thousand species of flies belonging to the genus *Drosophila* are now found throughout the world. About one-quarter of them live only in Hawaii. More than a thousand species of snails and other land mollusks are also only found in Hawaii. The explanation for the occurrence of such great diversity among closely similar forms is that the differences resulted from adaptive colonization of isolated environments by animals with a common ancestry. The Hawaiian Islands are far from, and were never attached to, any mainland or other islands, and thus they have had few colonizers. No mammals other than one bat species lived on the Hawaiian Islands when the first human settlers arrived; very many other kinds of plants and animals were also absent. The explanation is that these kinds of organisms never reached the islands because of their great geographic isolation, while those that reached there multiplied in kind, because of the absence of related organisms that would compete for resources.

Embryology, the study of biological development from the time of conception, is another source of independent evidence for common descent. Barnacles, for instance, are sedentary crustaceans with little apparent similarity to such other crustaceans as lobsters, shrimps, or copepods. Yet barnacles pass through a free-swimming larval stage, in which they look unmistakably like other crustacean larvae. The similarity of larval stages supports the conclusion that all crustaceans have homologous parts and a common ancestry. Human and other mammalian embryos pass through a stage during which they have unmistakable but useless grooves similar to gill slits found in fishes—evidence that they and the other vertebrates shared remote ancestors that respired with the aid of gills.

The substantiation of common descent that emerges from all the foregoing lines of evidence is being validated and reinforced by the discoveries of modern biochemistry and molecular biology, a biological discipline that has emerged in the mid twentieth century. This new discipline has unveiled the nature of hereditary material and the workings of organisms at the level of enzymes and other molecules. Molecular biology provides very detailed and convincing evidence for biological evolution.

The genetic basis of evolution

The central argument of Darwin's theory of evolution starts from the existence of hereditary variation. Experience with animal and plant breeding demonstrates that variations can be developed that are "useful to man." So, reasoned Darwin, variations must occur in nature that are favorable or useful in some way to the organism itself in the struggle for existence. Favorable variations are ones that increase chances for survival and procreation. Those advantageous variations are preserved and multiplied from generation to generation at the expense of less advantageous ones. This is the process known as *natural selection*. The outcome of the process is an organism that is well adapted to its environment, and evolution occurs as a consequence.

Biological evolution is the process of change and diversification of organisms over time, and it affects all aspects of their lives—morphology, physiology, behavior, and ecology. Underlying these changes are changes in the hereditary material (DNA). Hence, in genetic terms, evolution consists of changes in the organism's hereditary makeup. Natural selection, then, can be defined as the differential reproduction of alternative hereditary variants, determined by the fact that some variants increase the likelihood that the organisms having them will survive and reproduce more successfully than will organisms carrying alternative variants. Selection may be due to differences in survival, in fertility, in rate of development, in mating success, or in any other aspect of the life cycle. All these differences can be incorporated under the term *differential reproduction* because all result in natural selection to the extent that they affect the number of progeny an organism leaves.

Evolution can be seen as a two-step process. First, hereditary variation takes place; second, selection occurs of those genetic variants that are passed on most effectively to the following generations. Hereditary variation also entails two mechanisms: the spontaneous mutation of one variant to another, and the sexual process that recombines those variants to form a multitude of variations.

The information encoded in the nucleotide sequence of DNA is, as a rule, faithfully reproduced during replication, so that each replication results in two DNA molecules that are identical to each other and to the parent molecule. But occasionally "mistakes," or *mutations,* occur in the DNA molecule during replication, so that daughter molecules differ from the parent molecules in at least one of the letters in the DNA sequence. Mutations can be classified into two categories: gene, or point, mutations, which affect one or only a few letters (nucleotides) within a gene; and chromosomal mutations, which either change the number of chromosomes or change the number or arrangement of genes on a chromosome. Chromosomes are the elongated structures that store the DNA of each cell.

Newly arisen mutations are more likely to be harmful than beneficial to their carriers, because mutations are random events with respect to adaptation; that is, their occurrence is independent of any possible consequences. Harmful mutations are eliminated or kept in check by natural selection. Occasionally, however, a new mutation may increase the organism's adaptation. The probability of such an event's happening is greater when organisms colonize a new territory or when environmental changes confront a population with new challenges. In these cases there is greater opportunity for new mutations to be better adaptive. The consequences of mutations depend on the environment. Increased melanin pigmentation may be advantageous to inhabitants of tropical Africa, where dark skin protects them from the Sun's ultraviolet radiation; but it is not beneficial in Scandinavia, where the intensity of sunlight is low and light skin facilitates the synthesis of vitamin D.

Mutation rates are low, but new mutants appear continuously in nature because there are many individuals in every species and many genes in every individual. More important is the storage of variation, arisen by past mutations. Thus, it is not surprising to see that when new environmental challenges arise, species are able to adapt to them. More than two hundred insect species, for example, have developed resistance to the pesticide DDT in different parts of the world where spraying has been intense. Although the insects had never before encountered this synthetic compound, they adapted to it rapidly by means of mutations that allowed them to survive in its presence. Similarly, many species of moths and butterflies in industrialized regions have shown an increase in the frequency of individuals with dark wings in response to environmental pollution, an adaptation known as industrial melanism. The examples can be multiplied at will.

Dynamics of genetic change

The genetic variation present in natural populations of organisms is sorted out in new ways in each generation by the process of sexual reproduction. But heredity by itself does not change gene frequencies. This principle is formally stated by the Hardy-Weinberg law, an algebraic equation that describes the genetic equilibrium in a population.

The Hardy-Weinberg law plays in evolutionary studies a role similar to that of Isaac Newton's First Law of Motion in mechanics. Newton's First Law says that a body not acted upon by a net external force remains at rest or maintains a constant velocity. In fact, there are always external forces acting upon physical objects (gravity, for example), but the first law provides the starting point for the application of other laws. Similarly, organisms are subject to mutation, selection, and other processes that change gene frequencies, and the effects of these processes are calculated by using the Hardy-Weinberg law as the starting point. There are four processes of gene frequency change: mutation, migration, drift, and natural selection.

Mutations change gene frequencies very slowly, since mutation rates are low. *Migration,* or *gene flow,* takes place when individuals migrate from one population to another and interbreed with its members. The genetic make-up of populations changes locally whenever different populations intermingle. In general, the greater the difference in gene frequencies between the resident and the migrant individuals, and the larger the number of migrants, the greater effect the migrants have in changing the genetic constitution of the resident population.

Moreover, gene frequencies can change from one generation to another by a process of pure chance known as *genetic drift.* This occurs because populations are finite in numbers, and thus the frequency of a gene may change in the following generation by accidents of sampling, just as it is possible to get more or less than fifty "heads" in one hundred throws of a coin simply by chance. The magnitude of the gene frequency changes due to genetic drift is inversely related to the size of the population; the larger the number of reproducing individuals, the smaller the effects of genetic drift. The effects of genetic drift from one generation to the next are quite small in most natural populations, which generally consist of thousands of reproducing individuals. The effects over many generations are more important. Genetic drift can have important evolutionary consequences when a new population becomes established by only a few individuals, as in the colonization of islands and lakes. This is one reason why species in neighboring islands, such as those in the Hawaiian archipelago, are often more heterogeneous than species in comparable continental areas adjacent to one another.

Natural selection

Darwin proposed that natural selection promotes the adaptation of organisms to their environments because the organisms carrying useful variants leave more descendants than those lacking them. The modern concept of natural selection is defined in mathematical terms as a statistical bias favoring some genetic variants over their alternates. The measure to quantify natural selection is called *fitness*.

If mutation, migration, and drift were the only processes of evolutionary change, the organization of living things would gradually disintegrate because they are random processes with respect to adaptation. Those three processes change gene frequencies without regard for the consequences that such changes may have in the welfare of the organisms. The effects of such processes alone would be analogous to those of a mechanic who changed parts in a motorcar engine at random, with no regard for the role of the parts in the engine. Natural selection keeps the disorganizing effects of mutation and other processes in check because it multiplies beneficial mutations and eliminates harmful ones. Natural selection accounts not only for the preservation and improvement of the organization of living beings but also for their diversity. In different localities or in different circumstances, natural selection favors different traits, precisely those that make the organisms well adapted to the particular circumstances.

The origin of species

In everyday experience we identify different kinds of organisms by their appearance. Everyone knows that people belong to the human species and are different from cats and dogs, which in turn are different from each other. There are differences among people, as well as among cats and dogs; but individuals of the same species are considerably more similar among themselves than they are to individuals of other species. But there is more to it than that; a bulldog, a terrier, and a golden retriever are very different in appearance, but they are all dogs because they can interbreed. People can also interbreed with one another, and so can cats, but people cannot interbreed with dogs or cats, nor can these breed with each other. Although species are usually identified by appearance, there is something basic, of great biological significance, behind similarity of appearance; namely, that individuals of a species are able to interbreed with one another but not with members of other species. This is expressed in the following definition: *Species* are groups of interbreeding natural populations that are reproductively isolated from other such groups.

The ability to interbreed is of great evolutionary importance, because it determines that species are independent evolutionary units. Genetic changes originate in single individuals; they can spread by natural selection to all members of the species but not to individuals of other species. Thus, individuals of a species share a common gene pool that is not shared by individuals of other species, because they are reproductively isolated.

Adaptive radiation is a form of speciation that occurs when colonizers reach geographically remote areas, such as islands, where they find an opportunity to diverge as they become adapted to the new environment. Sometimes a multiplicity of new environments becomes available to the colonizers, giving rise to several different lineages and species. This process of rapid divergence of multiple species from a single ancestral lineage is called adaptive radiation.

Examples of speciation by adaptive radiation in archipelagos removed from the mainland have already been mentioned. The Galápagos Islands are about six hundred miles off the west coast of South America. When Darwin arrived there in 1835, he discovered many species not found anywhere else in the world—for example, fourteen species of finch (known as Darwin's finches). These passerine birds have adapted to a diversity of habitats and diets, some feeding mostly on plants, others exclusively on insects. The various shapes of their bills are clearly adapted to probing, grasping, biting, or crushing—the diverse ways in which these different Galápagos species obtain their food. The explanation for such diversity (which is not found in finches from the continental mainland) is that the ancestor of Galápagos finches arrived in the islands before other kinds of birds and encountered an abundance of unoccupied ecological opportunities. The finches underwent adaptive radiation, evolving a variety of species with ways of life capable of exploiting niches that in continental faunas are exploited by different kinds of birds. Some striking examples of adaptive radiation that occur in the Hawaiian Islands were mentioned earlier.

Rapid modes of speciation are known by a variety of names, such as *quantum, rapid,* and *saltational* speciation, all suggesting the short time involved. An important form of quantum speciation is *polyploidy,* which occurs by the multiplication of entire sets of chromosomes. A typical (diploid) organism carries in the nucleus of each cell two sets of chromosomes, one inherited from each parent; a polyploid organism has several sets of chromosomes. Many cultivated plants are polyploid: bananas have three sets of chromosomes, potatoes have four, bread wheat has six, some strawberries have eight. All major groups of plants have natural polyploid species, but they are most common among flowering plants (angiosperms) of which about forty-seven percent are polyploids.

In animals, polyploidy is relatively rare because it disrupts the balance between chromosomes involved in the determination of sex. But polyploid species are found in hermaphroditic animals (individuals having both male and female organs), which include snails and earthworms, as well as in forms with parthenogenetic females (which produce viable progeny without fertilization), such as some beetles, sow bugs, goldfish, and salamanders.

Gradual and punctuational evolution

Morphological evolution is by and large a gradual process, as shown by the fossil record. Major evolutionary changes are usually due to a building up over the ages of relatively small changes. But the fossil record is discontinuous. Fossil strata are separated by sharp boundaries; accumulation of fossils within a geologic deposit (stratum) is fairly constant over time, but the transition from one stratum to another may involve gaps of tens of thousands of years. Different species, characterized by small but discontinuous morphological changes, typically appear at the boundaries between strata, whereas the fossils within a stratum exhibit little morphological variation. That is not to say that the transition from one stratum to another always involves sudden changes in morphology; on the contrary, fossil forms often persist virtually unchanged through several geologic strata, each representing millions of years.

According to some paleontologists the frequent discontinuities of the fossil record are not artifacts created by gaps in the record, but rather reflect the true nature of morphological evolution, which happens in sudden bursts associated with the formation of new species. This proposition is known as the *punctuated equilibrium* model of morphological evolution. The question whether morphological evolution in the fossil record is predominantly punctuational or gradual is a subject of active investigation and debate. The argument is not about whether only one or the other pattern ever occurs; it is about their relative frequency. Some paleontologists argue that morphological evolution is in most cases gradual and only rarely jerky, whereas others think the opposite is true. Much of the problem is that gradualness or jerkiness is in the eye of the beholder.

DNA and protein evolution

The advances of molecular biology have made possible the comparative study of proteins and the nucleic acid DNA, which is the repository of hereditary (evolutionary and developmental) information. Nucleic acids and proteins are linear molecules made up of sequences of units—nucleotides in the case of nucleic acids, amino acids in the case of proteins—which retain considerable amounts of evolutionary information. Comparing macromolecules from two different species establishes the number of their units that are different. Because evolution usually occurs by changing one unit at a time, the number of differences is an indication of the recency of common ancestry.

Changes in evolutionary rates may create difficulties, but macromolecular studies have two notable advantages over comparative anatomy and other classical disciplines. One is that the information is more readily quantifiable. The number of units that are different is precisely established when the sequence of units is known for a given macromolecule in different organisms. The other advantage is that comparisons can be made even between very different sorts of organisms. There is very little that comparative anatomy can say when organisms as diverse as yeasts, pine trees, and human beings are compared; but there are homologous DNA and protein molecules that can be compared in all three.

Informational macromolecules provide information not only about the topology of evolutionary history, but also about the amount of genetic change that has occurred in any given branch. Studies of molecular evolution rates have led to the proposition that macromolecules evolve at fairly constant rates and, thus, that they can be used as evolutionary clocks, in order to determine the time when the various branching events occurred. The molecular evolutionary clock is not a metronomic clock, like a watch or other timepiece that measures time exactly, but a stochastic clock like radioactive decay. In a stochastic clock, the probability of a certain amount of change is constant, although some variation occurs in the actual amount of change. Over fairly long periods of time, a stochastic clock is quite accurate. The enormous potential of the molecular evolutionary clock lies in the fact that each gene or protein is a separate clock. Each clock "ticks" at a different rate—the rate of evolution characteristic of a particular gene or protein—but each of the thousands of genes or proteins provides an independent measure of the same evolutionary events.

Evolutionists have found that the amount of variation observed in the evolution of DNA and proteins is greater than is expected from a stochastic clock; in other words, the clock is inaccurate. The discrepancies in evolutionary rates along different lineages are not excessively large, however. It turns out that it is possible to time phylogenetic events with accuracy, but more genes or proteins must be examined than would be required if the clock were stochastically accurate. The average rates obtained for several DNA sequences or proteins taken together provide a fairly precise clock, particularly when many species are investigated.

See also ADAPTATION; DARWIN, CHARLES; ECOLOGY; FITNESS; GENETICS; LIFE, ORIGINS OF; LIFE SCIENCES; MUTATION; SELECTION, LEVELS OF; SOCIOBIOLOGY

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EVOLUTION, HUMAN

Human evolution is a field of science that falls within the larger area of physical anthropology. Human evolutionary studies are broadly synonymous with paleoanthropology, although paleoanthropology is a slightly wider concept that covers the host of fields contributing to the understanding of the human biological past in all its varied aspects. The central concern of human evolution involves sorting anatomical and behavioral differences within and among hominid species in order to delineate their ranges of variation through geological time and across geographical space. *Hominid* is often used as a colloquial term to indicate membership of fossil forms in the family *Hominidae,* the taxonomic group that includes anatomically and behaviorally modern humans and their precursors of the last six million years. The term *human* is a more subjective notion, whose limits can be debated. Some writers use it to include all members of the hominid family, while others restrict it to the genus *Homo* or to the species *Homo sapiens.*

In pre-evolutionary times, the Swedish naturalist Carolus Linnaeus (1707–1778), in his first edition of the *Systema Naturae* (1735), classified all organic organisms into a natural order using a hierarchical system with binominal nomenclature. He included humans (under the genus *Homo* and the species *sapiens,* derived from the Latin words for "man the wise"), along with lemurs, monkeys, and apes, in the order Primates. Intriguingly, in place of supplying physical characteristics to define this new species, Linnaeus avoided controversy by simply writing *nosce te ipsum* ("know thyself"). More than two and a half centuries later, physical anthropologists are still unable to agree on what constitutes modern humanity.

In terms of the morphological definition of modern humans, only a small number of unique anatomical characteristics stand out: (1) *Homo sapiens* is the only surviving member of the family *Hominidae,* a group anatomically committed to terrestrial bipedalism; (2) Members of this species have (not uniquely) relatively large brains—averaging 1,350 milliliters—with the most complex neocortex of all primates; (3) their chin-bearing faces are small compared to their neurocrania; and (4) they have a brow region structured into two parts. Behaviorally, modern humans are identified by the unique presence of: (1) a spoken language; (2) the cognitive faculties to generate mental symbols, as expressed in art; (3) the ability to think, reason, and plan; and (4) a bizarre inability to sustain prolonged bouts of boredom. Are anatomically modern humans and behaviorally modern humans the same thing? Not entirely. Anatomically and behaviorally modern humans appear in the archaeological and fossil records at different times.

Approximately one hundred thousand years ago, or perhaps somewhat earlier, anatomically modern humans appear in the fossil records of the Middle East and Africa; they are similar both cranially and postcranially to modern humans today, yet these earliest forms left no archaeological evidence to lead us to believe they had incorporated a modern behavioral repertoire. At seventy to fifty thousand years ago, we detect no change in the morphology of early anatomically modern humans, but there is dramatic evidence of a change in behavior. Splendid murals painted on the walls and ceilings of caves, musical instruments, and elaborate notations, together with a complex technology of stone and bone, are known from western Europe beginning about thirty thousand years ago. But these dramatic expressions were rather late, compared to the suggestions of similar symbolic behaviors known from as long ago as seventy thousand years, and maybe even more, in Africa. Similarly, modern humans had arrived in Australia by sixty thousand years ago, and an effectively modern level of cognition must have been present in these people to have allowed them to cross at least fifty miles of open ocean to get there. Obviously, a cognitive gulf was breached at some time after about seventy thousand years ago (perhaps earlier). This arose first of all in Africa, and spread thence to other parts of the world. Once *Homo sapiens* was in this behavioral mode, the speed of technological and other behavioral innovation (formerly episodic and rare) increased out of all proportion to what had gone before. At what point religious awareness was acquired is not known, but it was probably part of an overall biological potential for modern cognition that was achieved as a single "package." The huge range of behaviors made possible by this potential was only gradually discovered—and indeed, *Homo sapiens* is still enlarging its behavioral range today.

The human species and religious doctrine

By nature humans are inquisitive beings with an unquenchable thirst to understand and explain the meaning of life, especially their own. Since the days of the ancient Greek philosopher Aristotle (384–322 B.C.E.), the organic world had been looked upon as stable and unchanging, ascending steadily from the simplest forms to the most complex. Under the doctrine of the "Great Chain of Being," humans were perceived as godly creations and were positioned just below the angels on the top branch of a nicely ordered tree of life. All flora and fauna were designed for the purposes in nature that they were perceived to fulfill. The humanistic ideas of the Renaissance period centered all philosophy on human values and exalted human autonomy and superiority to the rest of nature. By the late seventeenth century, René Descartes's (1596–1650) philosophical idea that animals were complex machines with no higher sense of purpose had been expanded by French and German philosophers to create new foundations for a human social order. Morality was no longer considered to descend from an absolute truth enshrined in Christian beliefs, nor was the notion of accountability in the afterlife. The study of human nature became the key to understanding moral order in decent, complex societies. At a later period some struggled to integrate humans and nature with materialistic philosophy, but this view lost support during the turmoil of the French Revolution.

From Cuvier to Darwin

It would not be until the eighteenth century that the study of human origins became an approachable, but still controversial, topic within the budding science of natural history. Doubts raised by some natural historians questioned the interpretations of biblical literalists as to how humans came to exist on Earth, especially as increasing fossil discoveries in recognizably ancient sediments came to reveal that Earth's fauna did indeed appear to have a biological past. It was evident to naturalists that the Earth bore scars of an ancient history that contained puzzling geological phenomena, such as fossil fish on the tops of mountains, that were inexplicable within the boundaries even of the rudimentary scientific understanding that then existed.

It was impossible, then, to avoid the question as to where humans fitted into the picture. In 1830, the French naturalist Georges Cuvier's (1769–1832) treatise on fossil fauna and flora that was discovered in ancient geologic strata reported no evidence of human fossils coeval with these ancient genera. Since the geologic deposits involved varied greatly from one layer to the next, with bony evidence of once living creatures present in places where they had either gone extinct or now existed only on other continents, Cuvier reasoned that divinely instigated catastrophes and re-creations were responsible for the many extinction and replacement events he perceived. He argued that human fossils could be found if one were to look under the deepest of oceans, as suggested by the Old Testament's story of the great flood. Other naturalists, like Etienne Geoffroy Saint-Hilaire (1772–1844) and Jean Baptiste de Lamarck (1744–1829), provided strict evolutionary reasons for the drastic changes observed in the fossil record. Lamarck, for example, postulated that anatomical and behavioral changes acquired in a creature's lifetime might be passed on to its descendants. However, the Lamarckian paradigm of evolution would shift when two important events took place: (1) the 1858 announcement of Charles Darwin's (1809–1882) and Alfred Russel Wallace's (1823–1913) mechanism of natural selection to explain how species gradually change over time; and (2) the 1856 discovery (and the 1864 naming) of an extinct human species.

Charles Darwin, who rejected the basic tenets of the inheritance of acquired characteristics, enormously popularized a different evolutionary explanation for life on Earth with his the *On the Origin of Species,* published in 1859. Darwin proposed that biological organisms gradually evolve over time by adapting to their environments. Those individuals who are optimally suited to their environments end up producing more descendants than those who are not. If the features that make them better "adapted" are passed along by biological inheritance to their offspring, those features will become more common in the population, whose aspect will thus change over time. Keenly aware of the controversy it would generate, the retiring Darwin minimized any reference to humans in his publication, and did not broach the problem of human origins until many years later. Darwin's theory of "descent with modification" generated a great deal of controversy within religious and scientific communities. The highly public and politico-religious uproar that resulted centered on the distasteful suggestion that humans and apes share a common ancestor, especially in view of the long held belief that other animals are unable to think and are effectively nothing more than soulless automatons. Coming to Darwin's defense, Thomas Henry Huxley (1825–1895) fervently defended the tenets of Darwinian evolution, most publicly in his debate with Bishop Samuel Wilberforce (1805–1873) in 1860. In his influential 1863 publication of a series of public lectures titled *Evidence as to Man's Place in Nature,* Huxley argued that humans should be seen as biological organisms, and subject to the same natural laws that all other organic entities obey.

Interpreting the hominid fossils

The second epochal event for human evolutionary studies was the 1856 discovery of a fossil human at the Feldhofer Grotto in the Neander Valley, Germany. Most authorities of the day dismissed this find as the remains of a "barbarous" type of *Homo sapiens.* However, in 1864 the anatomist William King named the new form *Homo neanderthalensis,* thereby implying that there had been at least one ancient human extinction and speciation event. With further discoveries of the remains of extinct fossil humans, evolutionary concepts were more palatably applied to modern humans. The British geologist Charles Lyell (1797–1875), once a firm believer in God's role, abandoned many of his theological notions and accepted Darwin's theory of descent with modification after examining the remains of the Feldhofer Neanderthal.

At the turn of the twentieth century, the rediscovery of Mendelian genetics provided a basis for Darwin's evolutionary mechanism. Nonetheless, some paleontologists continued the attempt to integrate Christian beliefs with the idea of evolution. One such was the French Jesuit Pierre Teilhard de Chardin (1881–1955). While in Jesuit training in England, Teilhard also trained in paleontology and archaeology, and became embroiled in the Piltdown controversy that was just erupting. In 1912, he was invited to the Piltdown site in Sussex, which had yielded fossil bones including those of a human, and flint tools. Upon arrival he found a tooth. Reconstruction of the fragmentary hominid pieces seemingly offered the perfect transitional candidate from apes to humans—perhaps too perfect.

In 1912, "Piltdown Man" was introduced to the world as *Eoanthropus dawsoni.* At that time, the large brain was considered to be the hallmark of humanity; and for forty years British anatomists would disregard many significant fossil human discoveries because of their prized and large-brained Piltdown fossil. Teilhard later continued his paleontological research at the "Peking Man" site of Zhoukoudian in China. The Chinese fossils helped Teilhard to reconcile his now expansive knowledge of the human fossil record with his Christian beliefs. In *The Phenomenon of Man* (1938–1940), Teilhard proposed a theory of human evolution in which humans were evolving towards a final spiritual unity, also known as *Finalism.* This notion elicited the disapproval of his Jesuit superiors.

Early in the 1950s, Piltdown was exposed as a hoax—the doctored remains of a human and orangutan—and Teilhard has even been fingered as the hoaxer, though he remains only one of the more unlikely suspects of many. By the late 1950s the human fossil record had greatly expanded, as had the plethora of names used to describe it. A tidying-up was in order, and this was gradually achieved under a gradualist and progressivist model of human evolution.

In the 1970s and 1980s, new systematic methods began to transform the understanding of the constantly expanding human fossil record. Further, molecular studies were providing new perspectives. In particular, the "molecular clock" shortened the ape-human divergence to as little as five to six million years ago (from maybe twelve to fourteen). From around 1970 researchers uncovered bipedal but otherwise rather apelike hominids from sites in eastern Africa. These joined the *Australopithecus* fossils already known from southern Africa in the 2.5 to 1.5 million years ago range, and dated mostly from about 3.5 to 2.0 million years ago. Interpreted using an underlying gradualist model, these archaically-proportioned fossil hominids mostly reflected the search for an "earliest ancestor."

The situation at the beginning of the twenty-first century

Over the following few decades, hundreds of fossil human discoveries offered fuel for systematic debates. The "single species hypothesis," which stated that the human ecological niche was so wide that only one species of hominid could have existed at any one time, was rapidly invalidated by new finds, but still lingers in models of human origins that find deep roots in time for contemporary geographical groups of humankind. Evolutionary theory, as well as the rather sparse fossil record, imply in contrast that the species *Homo sapiens* must have had a single origin at one time and in one place, probably Africa. All of the human diversity familiar today has apparently appeared within the past 150 thousand years or so.

Despite minor differences of opinion, it is clear that the diversifying pattern of human evolution is similar to that of other mammalian taxa. Hominid phylogeny is a story of evolutionary experimentation, with multiple speciations and extinctions. The hominid family comprises at least five genera and eighteen known species (see Fig. 1, p. 302), some of which shared territories in both time and space. At present, all geographical varieties of modern humans occupy the single surviving twig of what appears once to have been a densely branching bush.

See also ANTHROPOLOGY; EVOLUTION; EVOLUTION, BIOCULTURAL; EVOLUTION, BIOLOGICAL; EVOLUTION, THEOLOGY OF; PALEOANTHROPOLOGY; PALEONTOLOGY; SOCIOBIOLOGY; TEILHARD DE CHARDIN, PIERRE

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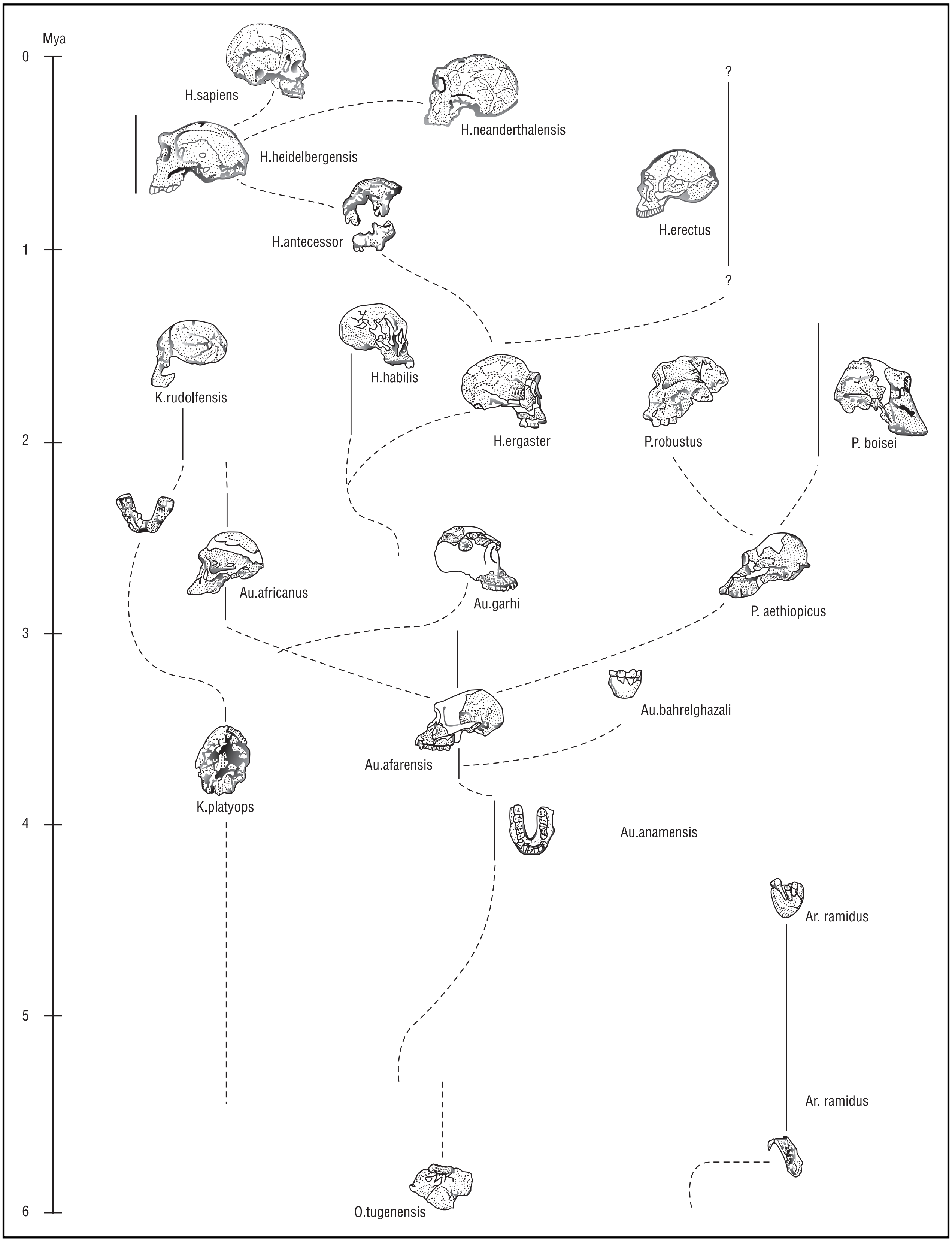
EVOLUTION, THEOLOGY OF

The term *theology of evolution* connotes the systematic study of the religious implications of biological evolution. Any intellectually plausible theology today must face the challenges arising from the notion of life's common descent and Charles Darwin's (1809–1882) theory of natural selection.

The dominant religious and theological traditions, where they have not been utterly hostile to it, have generally ignored evolutionary science. Consequently, when philosophers such as Daniel Dennett (b. 1942) refer to Darwinian evolution as "dangerous," partly because it seemingly destroys in principle any rational basis for religious life and thought, theologians must respond to such a provocation. However, the theological encounter with Darwinian science is not limited simply to an apologetic reaction to those scientists and philosophers who interpret evolution in terms of materialist philosophy. From the days of Darwin himself some theologians (for example, the Anglican Charles Kingsley) have eagerly embraced evolutionary biology as a great gift, one that allows theology to express its understanding of God in fresh


Mya
0
1
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H.sapiens
H.neanderthalensis
?
H.heidelbergensis
H.erectus
H.antecessor
?
H.habilis
K.rudolfensis
H.ergaster
P.robustus
P. boisei
Au.africanus
Au.garhi
P. aethiopicus
Au.bahrelghazali
Au.afarensis
K.platyops
Au.anamensis
Ar. ramidus
Ar. ramidus
O.tugenensis

Figure 1. One view of the diversity of fossil hominid species and of the relationships among them. Courtesy of Ian Tattersall.

and fertile ways. In the same spirit a theology of evolution continues the quest to understand religious views of deity in light of new scientific information about the story of life on earth.

That theology can enthusiastically appropriate evolution, however, may initially seem incompatible with the apparent randomness, waste, vast temporal duration, and blind natural selection associated with Darwin's theory of "descent with modification." According to the Darwinian theory, since organisms produce more offspring than are able to survive, some of these simply by chance will be better *adapted* than others to their habitats. The better-adapted organisms will on average produce more offspring than other members of the species, and so nature will *select* their descendants for survival. Over a long period of time this process of natural selection can account for all of the diversity in life, as well as for the intricate *design* in organisms.

The synthesis of Darwinian ideas with the more recent understanding of genetics, which explains variations in terms of mutations of genes, is generally known as *neo-Darwinism*. In the present entry, the term evolution will refer to the ideas of Darwin as well as those of neo-Darwinism.

The theory that all living forms descend with modification from a single source by way of the *mechanism* of natural selection has proven difficult for many religious people and theologians to embrace, especially when natural selection is presented, as it is by many scientists, as the adequate explanation of life's design and diversity. Evolutionists hold that the relative differences that render one organism more adaptive (reproductively fit) than others are apparently random or undirected. For theology this raises the question of whether life in particular, and the universe in general, might not be utterly devoid of any providential guidance. The competitive struggle for survival between the strong and the weak, in which the best adapted are selected and the ill-adapted perish, suggests that we live in an indifferent, impersonal universe. The entire process of evolution is accompanied by what seems to be an enormous amount of suffering, waste, and an unnecessary enormity of time, thus making us wonder what sense we could possibly make of the notion of an intelligent, compassionate God who truly cares for life, humans, and the universe.

All of the world's dominant religious traditions originated long before we had any inkling of the fascinating but shocking Darwinian account of life's story on earth. It would seem, therefore, that all of these religions, if they are to remain intellectually persuasive to their scientifically educated devotees, must now respond to evolutionary biology in ways other than simply ignoring or repudiating the neo-Darwinian convictions shared by the vast majority of contemporary scientists. So, even though the present entry focuses primarily on the implications of evolution for Western theology, much of what is said here may be applicable also to the religious thought of other traditions as they begin to look closely at the story of life on Earth.

Theological responses to Darwin

Theological responses to the Darwinian challenge fall naturally into three classes: opposition, separatism, and engagement. Here the first two will be given only brief treatment, since the third alone seems to encounter the science of evolution with the spirit of gratitude and enthusiasm that can lead to a constructive theology of evolution.

The first response is to insist that Darwinian evolution is incompatible with any religious or theological vision of the universe. The so-called creationists and scientific creationists can be located here. Interpreting the biblical creation accounts literally, creationists claim that Darwin's theory offers a whole new creation story, one that contradicts the biblical accounts. The idea of evolution seems to conflict with the accounts in Genesis of human origins and of the Fall. If there were no historical Adam and Eve and no "original sin" then, the creationists ask, what need would there be for a savior? Scientific creationists go even farther, claiming that the Scriptures give us a better scientific understanding of life's origin than do contemporary biologists.

Other representatives of this opposition response include contemporary proponents of *Intelligent Design Theory* such as Phillip Johnson, William Dembski, and Michael Behe. Representatives of this movement are not necessarily biblical literalists, but they view Darwinism as incompatible with every form of theism. Evolutionary science, at least in their view, is inseparable from philosophical naturalism or scientific materialism, a vision of reality that explicitly rules out the existence of God. Johnson, for example, repeatedly asserts that Darwinian biology is inherently atheistic and that secularists are now using evolutionary ideas as a weapon in a culture war whose objective is to topple traditional religious cultures and concomitant ethical values. Theologians from the second and third group (discussed below) likewise observe that at least some prominent Darwinians present evolutionary science in the guise of materialist ideology. However, they vehemently reject the assumption that evolutionary biology is inherently materialistic or atheistic.

The second of the three responses is the *separatist* one. Separatists are those who prefer in general to keep theology and science as far apart from each other as possible. They claim that unnecessary confusion on issues in science and religion occurs if we fail to distinguish scientific ideas from religious beliefs. In their view, theology deals with a completely different set of questions from those that scientists are asking. Theology is concerned with questions about God, human destiny, or ultimate meaning, whereas evolutionary science inquires about physical, efficient, material, or mechanical—that is, proximate—causes of events in nature. These two sets of questions, the religious and the scientific, are so distinct that, logically speaking, they cannot contradict each other. Consequently, since evolutionary theory is part of science, it cannot in principle be placed in a competitive relationship with theology. Many followers of the neo-orthodox theology of Karl Barth (1886–1968) as well as existentialist theologians fall in this separatist camp.

A good number of theologians, philosophers and scientists are comfortable with this separatist position. But others question whether this is the most courageous and fruitful approach that theology can take when it comes to evolution. A third position, *engagement,* goes further than separatism. It endorses the latter's concern to avoid conflating or confusing science and religion, but it advocates a more positive theology of evolution. Engagement theologians are aware that in the real world science inevitably affects our theological understanding. Evolutionary biology, therefore, will in some way influence our ideas of God. One can hardly expect to have precisely the same thoughts about ultimate reality after Darwin as people did before. Evolution, this third approach suggests, can even enrich our theological conceptions of God. Darwin's great idea, instead of being theologically dangerous (as the opposition camp holds) or simply innocuous (as the separatists maintain), may turn out to be a great stimulus to constructive theology. Recent examples include the contemporary work of Denis Edwards, John F. Haught, and Holmes Rolston III.

A theology of evolution does not seek refuge in pre-Darwinian design arguments, a quest that is destined to bring theology into unnecessary tension with science. Scientists, after all, seek to provide purely natural explanations of design, including the ordered complexity of living organisms; so the attribution of organic design directly to special divine intervention will be taken as an inappropriate intrusion of theology into an inquiry that lies in the domain of potential scientific illumination. Moreover, focus on design may cause us to ignore the randomness and disorder that accompany the emergence and evolution of life.

An understanding of God as self-emptying love, on the other hand, may provide the foundations for an evolutionary theology that neither interferes with scientific exploration nor edits out the messiness in Darwinian portraits of life. While it is obliged to reject what it takes to be the deadening materialist ideology within which neo-Darwinians often package their popular renditions of evolution, a theology of evolution based on a kenotic understanding of God as humble, self-giving love seems, at least to an increasing number of theologians, to be consonant with, and illuminative of, the astounding discoveries of evolutionary science itself. (The Greek word *kenosis* literally means "emptying").

Prospects for a theology of evolution

Theology, therefore, may begin its reflections on the life process by asking not whether evolution is compatible with the idea of an intelligent designer, but whether the sense of God as it is operative in actual religious awareness can, without in any way interfering with scientific work, plausibly contextualize the findings of evolutionary science. A theology rooted in actual religious experience is obliged to understand the natural world, including its evolutionary character, in terms of a specifically religious notion of God. And so, if the ultimately real is thought of by religious believers as endlessly self-emptying compassion, then theology must strive to understand Darwinian evolution as somehow consonant with such an understanding.

Evolutionary scientists, of course, will immediately want to know how any theology could plausibly reconcile trust in divine providence, the belief that God provides or cares for the world, with the fact of randomness or contingency in life's evolution. A theology of evolution would not try to brush this question aside with the reply that the idea of the "accidental" is simply a cover-up for human ignorance. Accident or chance is no illusion, but a very real aspect of nature. Moreover, an element of indeterminacy is just what theology should expect if the universe is grounded in a God whose essence, as Christians and others believe, is self-giving love. For if God really loves the world as something truly distinct from the divine being itself, then the cosmos must always have possessed some degree of autonomy, even during the long span of prehuman evolution. As even medieval philosopher and theologian Thomas Aquinas observed in *Summa Contra Gentiles*, there has to be room for contingency and chance in any universe that is distinct from God.

Not only indeterminacy, however, but also the remorseless regularity of the laws of nature, including natural selection, seems providential. If nature is not to dissolve into chaos at each instant of its becoming there must be a high degree of consistency to the cosmic process. In this respect, the impersonal rigidity of natural selection would not be regarded as any more theologically problematic than the laws of physics.

Furthermore, if nature is truly distinct from God, as most theists maintain, a theology of evolution would not be surprised that nature is given considerable amplitude for wandering about experimentally, as evolutionary biology has shown to be the case with life on earth. If God's creative and providential activity includes a liberating posture of letting the world be something distinct from God, rather than of manipulatively controlling it, theology can hardly be surprised that the world's creation does not take place in a single, once-and-for-all magical moment, but instead takes many billions of years. The reason theologians give for this temporal extravagance is that God cannot give the divine self, in grace and unrestricted love, to a universe that is not first allowed to be itself, that is, something truly "other" than God. We may wonder, then whether a universe created instantaneously in complete finished perfection would possess the requisite "otherness" to be loved by its creator.

Of course, to scientists skeptical of theology the prodigality of evolution's multi-millennial journey seems impossible to reconcile with a religious trust in divine intelligence and providence. Surely, if God were intelligent and all-powerful, creation would never have taken so long or ambled so awkwardly over thirteen or so billions of years. Here the scientific skeptics would be joined by creationists and intelligent design defenders in a common objection: a truly competent creator would not have gone about the business of creating a universe in so bumbling a fashion as Darwin's science has pictured it.

However, a theology of evolution would argue that a God of love wills the independence of the universe, and that all of the evolutionary indeterminacy in the journey of life is consistent with the idea of a God who longs for a universe of emergent freedom. A theology of evolution would even claim that any universe embraced by divine love must inevitably have the opportunity to try out many different ways of existing. Evolution's randomness and deep temporal duration, therefore, are not necessarily signs of a universe devoid of providence, but are features that could be seen as essential to the genuine emergence of what is truly other than God.

A theology of evolution portrays providence, therefore, as rejoicing in the evolving autonomy of a self-creating universe. It claims that only a narrowly coercive deity would have collapsed what is in fact a long and dramatic story of creation into the dreary confines of a single originating instant. Instead of freezing nature into a state of finished perfection, a God of love would generously endow the universe with ample scope to become a self-coherent world rather than letting it be a passive, puppet-like appendage of deity. A divine providence that assumes the character of self-humbling love would risk allowing the cosmos to exist and unfold in relative liberty. And so the story of life would take on an evolutionary character not in spite of but because of God's care for the cosmos. For this reason, attempts to cover up the messiness of evolution by portraits of nature as consisting essentially of order or design devised by an intelligent designer would be taken as theologically impoverishing.

A theology of evolution, therefore, revels in Darwin's ragged vision of life rather than trying to trim off its uneven edges. It maintains that evolution may help theology realize more clearly than ever that God is more interested in promoting freedom and arousing adventure in the world than in preserving the status quo or legislating impeccable design. Biblical faith has always been aware of God's concern for human liberation. Now evolutionary science allows theology to connect its ideas of a liberating deity more expansively to the larger story of life's ageless emancipation from triviality.

What then about the problems of original sin, evil, and the fact of suffering in evolution? The idea of original sin after Darwin cannot refer literally to events in a historically factual Eden. One interpretation then is that original sin means that each person is born into a world already vitiated by humanity's habitual turning away in despair from the imperatives of life and the evolutionary adventure of self-transcendence. Furthermore, as Jesuit geologist and paleontologist Teilhard de Chardin (1881–1955) often noted, as long as the universe remains unfinished it will have a dark side to it. Original sin and evil in general cannot be understood apart from the fact that the universe has not yet been perfected. In this context, one meaning of *sin* would be our deliberate resistance to the world's ongoing evolution. An unfinished universe allows for hope, and an evolutionary theology would claim that the world's inhabitants are given the opportunity to participate in the momentous work of continuing creation. Not to do so would, in an evolutionary context, be disobedience to the will of God.

Finally, an evolutionary theology would also extend the picture of God's empathy far beyond the human sphere so as to have it embrace and redeem all the struggle and pain in the entire emergent universe. It sees God as responsively enfolding the whole of creation and not just human history.

See also EVIL AND SUFFERING; EVOLUTIONARY EPISTEMOLOGY; EVOLUTIONARY ETHICS; HUMAN NATURE, RELIGIOUS AND PHILOSOPHICAL ASPECTS; KENOSIS; SIN; THEODICY

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JOHN F. HAUGHT

EXAPTATION

See GOULD, STEPHEN J.; ADAPTATION

EXOBIOLOGY

Exobiology, also known as *astrobiology* and *bioastronomy,* is the study of the potential for life beyond Earth and the active search for it. Nobel geneticist Joshua Lederberg coined the term *exobiology* in 1960, and the field grew significantly with space exploration, especially the Viking landers on Mars. Exobiology draws largely from four disciplines: planetary science, planetary systems science, origins of life studies, and the Search for Extraterrestrial Intelligence (SETI). The field has been invigorated by claims of fossil life in an ancient Mars rock, the discovery of a possible ocean on the Jovian moon Europa, extrasolar planets around sun-like stars, life in extreme environments on Earth, and complex organic molecules in interstellar molecular clouds. Life itself, however, has not yet been found beyond Earth.

See also EXTRATERRESTRIAL LIFE

STEVEN J. DICK

EXPERIENCE, RELIGIOUS: COGNITIVE AND NEUROPHYSIOLOGICAL ASPECTS

In a neurocognitive approach to the study of religious and spiritual experiences, it is important to consider two major avenues towards attaining such experiences: (1) group ritual, and (2) individual contemplation or meditation. A phenomenological analysis reveals that the two practices are similar in kind, if not intensity, along two dimensions: (1) intermittent emotional discharges involving the subjective sensations of awe, peace, tranquility, or ecstasy; and (2) varying degrees of unitary experience correlating with the emotional discharges. These unitary experiences consist of a decreased awareness of the boundaries between the self and the external world, sometimes leading to a feeling of oneness with other perceived individuals, thereby generating a sense of community.

The experiences of group ritual and individual meditation overlap to a certain degree, such that each may play a role in the other. In fact, it may be that human ceremonial ritual provides the "average" person access to mystical experience ("average" in distinction to those who regularly practice intense contemplation, such as highly religious monks). This by no means implies that the mystic or contemplative is impervious to the effects of ceremonial ritual. Precisely because of the intense unitary experiences arising from meditation, mystics are likely to be more affected by ceremonial ritual than the average person. Because of the essentially communal aspect of ritual, it tends to have immeasurably greater social significance than individual meditation or contemplation. However, meditation and contemplation, almost always solitary experiences, typically produce unitary states that are more intense and more extended than the relatively brief flashes generated by group ritual.

Human ceremonial ritual is a morally potent technology. Depending on the myths and beliefs in which it is imbedded and which it expresses, therefore, ritual can either promote or undermine both the structural aspects of a society and overall aggressive behavior. In *The Ritual Process* (1969) Victor Turner uses the term *communitas* to refer to the powerful unitary social experience that usually arises out of ceremonial ritual. If a myth achieves its incarnation in a ritual that defines the unitary experience as applying only to the tribe, then the result is *communitas tribus.* It is certainly true that aggression within the tribe can be minimized or eliminated by the unifying experience generated by the ritual. However, this may only serve to emphasize the special cohesiveness of the tribe in relation to other tribes. The result may be an increase in intertribal aggression, even though intra-tribal aggression is diminished. The myth and its embodying ritual may, of course, apply to all members of a religion, a nation state, an ideology, all of humanity, or all of reality. As one increases the scope of what is included in the interpretation of the experience, the amount of overall aggressive behavior decreases. If indeed a ceremonial ritual gave flesh to a myth of the unity of all being, then one would presumably experience a brief sense of *communitas omnium.* Such a myth-ritual experience approaches meditative states, such as the "cosmic consciousness" described in 1961 by Richard Bucke, or even the "Absolute Unitary Being" described in Eugene d'Aquili and Andrew Newberg's *Mystical Mind* (1999). However, such grand scope is normally unusual for group ritual.

A neurocognitive perspective on spiritual experiences

It appears that there are a variety of spiritual experiences that may seem to be different, but actually have a similar neurocognitive origin, and therefore, lie along a continuum. This continuum might be thought of from a unitary experiential perspective. On one end of the spectrum are experiences such as those attained through participating in a church liturgy or watching a sunset. These experiences carry with them a mild sense of being connected with something greater than the self. On the other end of the spectrum are the types of experiences usually described as mystical or transcendent. This unitary element of spiritual experience should not be thought of as limiting the specific aspects and experiences associated with them. It simply appears to be the case that unitary feelings are a crucial part of spiritual experiences. Most scholars have focused on the more intense experiences because of ease of study and analysis—the most intense experiences provide the most robust responses, which can be qualitatively and perhaps even quantitatively measured. For example, in "Language and Mystical Awareness" (1978), Frederick Streng described the most intense types of spiritual experiences as relating to a variety of phenomena, including occult experience, trance, a vague sense of unaccountable uneasiness, sudden extraordinary visions and words of divine beings, or aesthetic sensitivity. In *The Religious Experience of Mankind* (1969), Ninian Smart distinguished mysticism from an experience of "dynamic external presence." Smart argued that certain sects of Hinduism, Buddhism, and Daoism differ markedly from prophetic religions, such as Judaism and Islam, and from religions related to the prophetic-like Christianity, in that the religious experience most characteristic of the former is "mystical," whereas that most characteristic of the latter is "numinous."

Similar to Smart's distinction between mystical and numinous experiences is the distinction Walter T. Stace makes in *Mysticism and Philosophy* (1960) between what he calls "extrovertive" and "introvertive" mystical experiences. According to Stace, extrovertive mystical experiences are characterized by: (1) a "Unifying Vision" that all things are one; (2) a concrete apprehension of the "One" as an inner subjectivity, or life, in all things; (3) a sense of objectivity or reality; (4) a sense of blessedness and peace; (5) a feeling of the holy, sacred, or divine; (6) paradoxicality; and (7) that which is alleged by mystics to be ineffable. Introvertive mystical experiences are characterized by: (1) "Unitary Consciousness," or the "One," the "Void," or pure consciousness; (2) a sense of nonspatiality or nontemporality; (3) a sense of objectivity or reality; (4) a sense of blessedness and peace; (5) a feeling of the holy, sacred, or divine; (6) paradoxicality; and (7) that which is alleged by mystics to be ineffable. Stace then concludes that characteristics 3 through 7 are identical in the two lists and are therefore universal common characteristics of mystical experiences in all cultures, ages, religions, and civilizations of the world. Characteristics 1 and 2 ground the distinction between extrovertive and introvertive mystical experiences in his typology. There is a clear similarity between Stace's extrovertive mystical experience and Smart's numinous experience, and between Stace's introvertive mystical experiences and Smart's mystical experience.

A neurocognitive analysis of mysticism and other spiritual experiences might clarify some of the issues regarding mystical and spiritual experiences by allowing for a better typology of such experiences based on the underlying brain structures and their related cognitive functions. In terms of the effects of ceremonial ritual, rhythmicity in the environment (visual, auditory, or tactile) drives either the *sympathetic* nervous system, which is the basis of the fight or flight response and general levels of arousal, or the *parasympathetic* nervous system, which is the basis for relaxing the body and rejuvenating energy stores. Together, the sympathetic and parasympathetic systems comprise the *autonomic* nervous system, which regulates many body functions, including heart rate, respiratory rate, blood pressure, and digestion. During spiritual experiences, there tends to be an intense activation of one of these systems, giving rise to either a profound sense of alertness and awareness (sympathetic) or oceanic blissfulness (parasympathetic). It has also been shown that both the sympathetic and the parasympathetic mechanism might be involved in spiritual experiences since such experiences contain both arousal and quiescent-like cognitive elements.

For the most part, this neurophysiological activity occurs as the result of the rhythmic driving of ceremonial ritual. This rhythmic driving may also begin to affect neural information flows throughout the brain. The brain's posterior superior parietal lobe (PSPL) may be particularly relevant in this regard because the inhibition of sensory information may prevent this area from performing its usual function of helping to establish a sense of self and distinguishing discrete objects in the environment. The result of this inhibition of sensory input could result in a sense of wholeness becoming progressively more dominant over the sense of the multiplicity of baseline reality. The inhibition of sensory input could also result in a progressive loss of the sense of self. Ceremonial ritual may be described as generating these spiritual experiences from the "bottom-up," since it is through rhythmic sounds and behaviors that rituals eventually drive the sympathetic and parasympathetic systems and, ultimately, the higher order processing centers in the brain. In addition, the particular system initially activated depends upon the type of ritual. Rituals themselves might therefore be divided into the "slow" and the "fast." Slow rituals involve, for example, peaceful music and soft chanting to generate a sense of quiescence via the parasympathetic system. Fast rituals might include, for example, frenzied dancing to generate a sense of heightened arousal via the sympathetic system.

Individual practices like prayer or meditation may also access a similar neuronal mechanism, but from the "top-down." In such a practice, a person begins by focusing the mind as dictated by the particular practice, thereby affecting higher-level processing areas of the brain and ultimately the autonomic nervous system. For example, a meditation practice in which the person focuses on a visualized object of spiritual significance might begin with activation of the brain's prefrontal cortex (PFC), which is normally active during attention-focusing tasks. The continuous fixation on the image by the areas of the brain responsible for high order visual processing begins to stimulate the limbic system, which is primarily involved in emotional processing and memory. Several scholars have implicated this area as critical for religious experience because of its ability to label experiences as profound or real and also because certain pathological conditions, such as seizures in the limbic areas, have been particularly associated with extreme religious experiences. The limbic system is connected to a structure called the hypothalamus, making it possible to communicate the activity occurring in the brain to the rest of the body. The hypothalamus is a key regulator of the autonomic nervous system, and therefore such activity in the brain ultimately activates the arousal (sympathetic) and quiescent (parasympathetic) arms of the autonomic nervous system. Part of the result of meditation and other spiritually oriented practices is also to block sensory input into the PSPL, resulting in a loss of the sense of self and a loss of awareness of discrete objects. Thus, a comparison of ceremonial ritual and individual practices like meditation suggests that the end result can be the same for both. It is, of course, difficult to attain the same degree of spiritual experience through ritual as through meditation, because the former requires the maintenance of the rhythmic activity necessary for the continued driving of neurocognitive systems. However, ceremonial ritual still can result in powerful unitary experiences.

The cognitive state in which there is a unity of all things, including the self, the world, and objects in the world, is described in the mystical literature of all the world's great religions. When a person is in that state all sense of discrete being is lost and the difference between self and other is obliterated. There is no sense of the passage of time, and all that remains is a timeless undifferentiated consciousness. When such a state is suffused with positive affect there is a tendency to describe the experience, after the fact, as personal. Such experiences may be described as a perfect union with God, as in the *unio mystica* of the Christian tradition, or else the perfect manifestation of God in the Hindu tradition. When such experiences are accompanied by neutral affect they tend to be described, after the fact, as impersonal. These states are described in concepts such as the "abyss" of Jacob Boeme, the "void" or "*nirvana*" of Buddhism, or the "absolute" of a number of philosophical and mystical traditions. There is no question that whether the experience is interpreted personally as God or impersonally as the "absolute" it nevertheless possesses a quality of transcendent wholeness without any temporal or spatial division.

Techniques for studying spiritual experiences

Clearly, one of the most important aspects of a study of spiritual experiences is to find careful, rigorous methods for empirically testing hypotheses. One such example of empirical evidence for the neurocognitive basis of the spiritual experiences described above comes from a number of studies that have measured neurophysiological activity during states in which there is activation of the holistic operator. Meditative states comprise perhaps the most fertile testing ground because of the predictable, reproducible, and well-described nature of such experiences. Studies of meditation have evolved over the years to utilize the most advanced technologies for studying neurophysiology.

Originally, studies analyzed the relationship between meditative states and electrical changes in the brain as measured by electroencephalography (EEG). Proficient meditation practitioners have been shown to demonstrate significant changes in the electrical activity in the brain, particularly in the frontal lobes. Furthermore, the EEG patterns of meditative practice indicate that it represents a unique state of consciousness different from normal waking and sleep. Unfortunately, EEG is limited in its ability to distinguish particular regions of the brain that may have increased or decreased activity.

For this reason, more recent studies of meditation have used brain imaging techniques, such as single photon emission computed tomography (SPECT), positron emission tomography (PET), and functional magnetic resonance imaging (fMRI). Since about 1990, neuroimaging techniques have been used to explore cerebral function during various behavioral, motor, and cognitive tasks. These studies have helped to determine which parts of the brain are responsible for a variety of neurocognitive processes. These imaging techniques have also allowed for the uncovering of complex neural networks and cognitive modules that have become a basis for cognitive neuroscience research. Activation studies using these functional neuroimaging techniques have helped researchers determine the areas in the brain that are involved in the production and understanding of language, visual processing, and pain reception and sensation. In a typical activation study, the subject is asked to perform such tasks as reading and problem solving while being scanned, and the activation state during the task is then compared to some control state (usually resting). Since most spiritual practices and their concomitant experience might be considered from the perspective of an activation paradigm, functional brain imaging techniques may be extremely useful in detecting neurophysiological changes associated with those states. Researchers can also use PET and SPECT to explore a wide variety of neurotransmitter systems within the brain. Neurotransmitter analogues have been developed for almost every neurotransmitter system, including the dopamine, benzodiazepine, opiate, and cholinergic receptor systems.

There are limitations in each technique for the study of meditation. It is important to ensure that the technique is sensitive enough to measure the changes. Also, each of these techniques may interfere with the normal environment in which spiritual practices take place. Early data of meditative practices has generally shown increases in brain activity in the region comprising the PFC, consistent with focusing attention during meditation. Studies have also observed decreases of activity in the area of the PSPL, possibly consistent with inhibition of sensory input into this area. However, more studies, with improved methods will be necessary to elucidate the neurocognitive aspects of meditation and spiritual experiences. That the underlying neurophysiology of extreme meditative states can be considered at all allows for the conceptualization of many other spiritual experiences that lie along the spiritual continuum.

In all, these studies can provide a starting point to develop a more detailed neurocognitive model of religious and spiritual experience. This kind of analysis can also be utilized as the hypothesis for future investigations of such experiences.

See also CONSCIOUSNESS STUDIES; EXPERIENCE, RELIGIOUS: PHILOSOPHICAL ASPECTS; MIND-BODY THEORIES; MIND-BRAIN INTERACTION; NEUROSCIENCES

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ANDREW B. NEWBERG

EXPERIENCE, RELIGIOUS: PHILOSOPHICAL ASPECTS

Although Protestants had previously used the phrase *religious experience* as a rough synonym for spiritual biography, William James (1842–1910) first employed *religious experience* to denote a generic category, applicable to all religions and susceptible to scientific analysis. James's *The Varieties of Religious Experience* (1902) gave the new category a broad extension. He described his topic as "personal religion in the inward sense," contrasted with institutional religion and theology (p. 42). From a psychological standpoint James aimed to provide a "descriptive survey of the religious propensities" (p. 22), including religious feelings and emotions, religious impulses, religious motivations, and nonritualized religious actions. James's methodological decision to focus on the extreme expressions of personal religion exhibited by "religious geniuses" (p. 24) has contributed to a tendency to narrow the category of religious experience to include primarily extraordinary, paranormal experiences and mystical states of consciousness.

With his "descriptive survey of the religious propensities," James hoped to contribute to a "Science of Religions" as he conceived it. His Science of Religions would distill the beliefs of various religions until they harmonized with each other, and then formulate hypotheses that reconciled this universal content with the rest of science. James identified as common to religions the consciousness of something "more" that is continuous with the higher part of oneself. To render this generalized religious content palatable to science, he invoked the subconscious. He hypothesized that "whatever it may be on its farther side, the 'more' with which in religious experience we feel ourselves connected is on its hither side the subconscious continuation of our conscious life" (p. 386). James believed that a Science of Religions would commend itself to believer and scientist alike, and could prove as credible as the natural sciences. Though others too have hoped to reconcile science and religious experience, few have entertained so sanguine an expectation.

An early theory

Despite the fact that James adopted the term *religious experience* at the turn of the twentieth century, the scientific interest in what James and later thinkers would call *religious experience* dates to the eighteenth century. David Hume's (1711–1776) essay "Of Superstition and Enthusiasm" (1741) represents one of the earliest psychological explanations of religious experience. It attempts, moreover, a sociology of religious experience. With the notable exception of Emile Durkheim's (1858–1917) *The Elementary Forms of Religious Life* (1912), most later theories focus exclusively on either the psychology of religious experience or the sociology of religious experience—its social determinants and social uses. Hume wanted to establish general principles with which to explain human nature (moral philosophy) in the same way that Newton had established general principles with which to explain physical nature (natural philosophy). Hume drew on his science of human nature to explain religion. Superstition and enthusiasm, he argued, represent different implicit explanations of anomalous emotional states. A superstitious person, ignorant of the physiological cause of objectless fear, attributes it to the existence of invisible malevolent beings who require appeasement through rites and mortifications. An enthusiast, by contrast, ignorant of the physiological cause of unwarranted hope or pride, attributes it to divine inspiration and experiences transports, raptures, and ecstasies. In both cases the subject resorts to imaginary causes to satisfy an explanatory interest.

Hume believed that the proportions of superstition and enthusiasm in a religion had important social consequences. He argued that superstition requires priests to interpose on behalf of the cowed fearful, whereas enthusiasm will not abide priests because the enthusiast believes his sacred commerce with God obviates institutions and their representatives. Enthusiastic religions begin tumultuously, even violently, but quickly moderate because their weak institutional structure cannot sustain the fervor. Nevertheless, enthusiasm's spirit of self-reliance and autonomy bolsters civil liberty. Superstition, by contrast, gains ground gradually by taming its adherents and ends in tyranny. Despite the fact that Hume emphasizes only the influence an individual's emotions have on his religion and overlooks the extent to which the doctrines of a religion inform the quality of the individual's emotions, his account is superior to many later theories for at least one major reason. Hume stresses the cognitive nature of religious experience, that explanatory commitments are constitutive of religious experience. The subject's own tacit or implicit commitments about the proper explanation of the experience are what makes the experience the experience it is. Many later theorists, including James, elide this feature of religious experience.

Polemics and apologetics

Hume's theory had a polemical tenor. He labeled both superstition and enthusiasm "species of false religion" (p. 73), and the essay has a political subtext. Hume is instructive in this regard. The study of religious experience, like the study of religion itself, had its origin in polemics and apologetics. This history explains the contours of the concept. Religious experience was forged in response to the modern challenge to religion. Since the Enlightenment, rational inquiry had impugned the traditional sources of religious knowledge. Baruch Spinoza (1632–1677) and the subsequent development of higher textual criticism undermined scriptural authority. The creation of modern probability theory eroded the once intrinsic connection between doctrinal authority and credibility. Hume and Immanuel Kant (1724–1804) effectively thwarted the aspiration for natural theology, while Hume, furthermore, produced what he called a "check" against the credibility of miracle claims. By way of rejoinder, apologists turned to spiritual or mystical experience as a ground for religious commitment. They argued that religious experience is cognitively immediate (i.e., not influenced by, or a product of, prior beliefs) and, therefore, unassailable by rational and historical inquiry into the defensibility of religious beliefs. If religious experience were, in part, a product of prior religious beliefs, one could not use religious experience as an independent ground for religious commitment. Armed with this understanding of religious experience, the increasing exposure to the vast diversity of religions presented not a challenge, but a defense in numbers. Despite incompatible beliefs and practices, all religions at bottom stem from the same or similar experiences, feelings, or sentiments.

Friedrich Schleiermacher (1768–1834) inaugurated this apologetic conception of religious experience. In *On Religion: Speeches to its Cultured Despisers* (1799) he explained that religion consists in piety, a distinct moment of consciousness that he construed as "a sense or taste for the Infinite." In his later systematic theology, *The Christian Faith* (1830) he described piety as the "feeling of absolute dependence" that accompanies all self-consciousness. In both works he sharply distinguished piety from belief and insisted on the immediacy of piety. Ultimately, he heralded an "eternal covenant" between science and religion, whereby religion allows to science all that is of interest to it (1981, pp. 64–65). The immediate, noncognitive nature of piety, he claimed, eliminated the possibility of a conflict. The tendency to treat religious experience as immediate and to consider it the source of religion became widespread after Schleiermacher. Despite James's refusal to distinguish sharply between feelings and beliefs in his more psychological and philosophical works, he too displays this tendency in *The Varieties of Religious Experience* when he claims that personal religious feelings are immediate, primordial, and ultimately productive of beliefs.

Naturalistic explanations of religious experience, such as Hume's, had their effect on the concept of religious experience as well. Ann Taves, in her book *Fits, Trances, and Visions* (1999) has shown how American religious groups, especially among the elite, tended to construct their notions of genuine religious experience by contrasting it with experiences that could be explained naturalistically. Furthermore, they often adopted the naturalistic explanations for experiences they wished to discourage. In the eighteenth century, for instance, Jonathan Edwards (1703–1758), the Calvinist divine, distinguished in his mature writings between genuine religious affections and enthusiasm, the latter involving "imaginary ideas . . . strongly impressed upon the mind" (Taves, p. 39). In the nineteenth century, religious explanations of religious experience continued to compete with naturalistic explanations, now phrased in terms of mesmerism. Seventh Day Adventists and Christian Scientists explained false religion by invoking mesmerism, while mainline denominations tended likewise to dismiss the experiences of Adventists and Christian Scientists as products of mesmerism. Some religious movements, such as Spiritualism, embraced mesmerism as a natural and sufficient means for attaining access to the spirit world and, therefore, attempted a form of religious naturalism. Taves's work demonstrates that thought about religious experience has implicitly been thought about naturalistic explanation as well.

The polemical and apologetic history informing the concept of religious experience has shaped its connotation. The concept suggests ethereal experiences like those that have come to be called mystical because these states seem more resistant to naturalistic explanation, more plausibly immediate, and more promising as a ground for religious commitment than somatic automatisms or visionary experience. The latter seem pathological and best explained naturalistically. James's ultimately unsuccessful labors to neutralize "the bugaboo of morbid origin" in the very first chapter of *The Varieties of Religious Experience,* before even defining his topic, reflects this concern to hedge religious experience from pathology (p. 35). The insistence in many mystical texts on ineffability—that the experience cannot be described—has lead many to consider mystical states of consciousness the paradigmatic religious experiences. Ineffability is taken to signal immediacy. The modern interest in religious experience has frequently led to interpretive mistakes. Some religious thinkers engaged in negative theology, such as Pseudo-Dionysius, who assert the ineffability of its conclusions, have been mistakenly read as describing altered states of consciousness.

Contextualists and perennialists

The alleged immediacy of mystical states continues to be a point of controversy in the study of religious experience. So-called contextualists or constructivists follow in Hume's footsteps. They argue for the cognitive nature of religious experience. In *Religious Experience* (1985) Wayne Proudfoot argued on logical grounds that the subject's implicit explanation of their experience in religious terms makes their experience a religious experience. The commitments the subject harbors about the causes of their experience and the terms appropriate to describe it are constitutive of the experience. They determine its intentionality, or what the experience is of. For this reason subjects who adopt commitments derived from different religious traditions have different experiences. Proudfoot argues, moreover, that one should not understand the ineffability reported in mysticism as an unanalyzable, descriptive characteristic of experience indicating its immediacy but rather as a feature of the theological concepts and commitments informing the intentionality of the experience.

So-called perennialists follow in Schleiermacher's footsteps. They argue for the immediacy of certain forms of religious experience. Robert Forman has argued largely on phenomenological grounds for the existence of states of wakeful, nonintentional consciousness. He calls episodes of this state of contentless consciousness *Pure Consciousness Events* (PCEs). They are nonintentional because they are not experiences of anything. Forman sees evidence of PCEs in a number of meditative traditions around the world. Because PCEs have no content, he claims, they cannot be culturally specific. Mystics of any tradition achieving PCEs have the qualitatively identical ineffable experience. Contextualists reply that the textual evidence adduced by perennialists does not support the assertion of a cross-cultural uniformity of experience. They also argue that phenomenological descriptions of what feels like contentless consciousness do not necessarily mean that the experiences are immediate (i.e., unconditioned by prior beliefs). Regardless, one should note that even if Forman has indeed identified a form of contentless, immediate consciousness, that fact has no intrinsic religious significance. Religious significance could only come ex post facto from interpretation. Because PCEs have no intrinsic religious import, they cannot by themselves serve the apologetic motivations that inspire the search for immediate experience.

Neuroscience

Advances in neurobiology have fostered the hope that a better understanding of the brain can explain religious experience. For some scholars brain function (or malfunction) provides models for accounts of extraordinary religious states. Michael Persinger, for instance, observes the similarities between the psychological effects produced by temporal lobe epilepsy and what he calls "God Experiences." On this basis and with no intention of stigmatizing religion, he infers that transient electrical microseizures in the temporal lobe of the brain explain "God Experiences." Eugene d'Aquili and Andrew Newberg offer a different neurological explanation of religious experience. They provide a complex model whereby ritual and meditation, by different routes, lead to the activation of the autonomic nervous system. This stimulation, in conjunction with the subsequent activation of some and isolation of other higher brain areas, creates various forms of religious experience, including contentless mystical states of Absolute Unitary Being (AUB). Like Schleiermacher and James, they view religious experience as the source of theology and institutions. They maintain that these circuits of neurophysiological stimulation, which affect areas of the brain responsible for causal and holistic cognition, produce religious concepts and even mystical traditions. D'Aquili and Newberg's theory is generally considered highly speculative. It also slights the cognitive dimension of religious experience. The physiological underpinning or component of experience does not suffice to make an experience a religious experience. The subject's implicit commitment to a religious explanation of the experience makes an experience a religious experience. To this extent a social or cultural explanation of religious experience is necessary. Neurology by itself is insufficient.

See also CONSCIOUSNESS STUDIES; EXPERIENCE, RELIGIOUS: COGNITIVE AND NEUROPHYSIOLOGICAL ASPECTS; HUME, DAVID; MIND-BODY THEORIES; MIND-BRAIN INTERACTION; MYSTICISM; NEUROSCIENCES; PSYCHOLOGY OF RELIGION; SOCIOLOGY

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MATTHEW C. BAGGER

EXPLANATION

When one wants to understand something, one asks for an explanation. In principle, everything can be the object of explanation. Some explanations, such as in classification and interpretation, explain *what* something is: What is a whale? It is a mammal; Could you explain the movie *Dr. Strangelove* to me? It is about the Cold War. Some explanations explain *how* something works or how something is possible: How does the door open? Press the button; How is it possible that some children survive the most cruel experiences? There are adults who love them and care about them. Finally, some explanations explain *why* something happens: Why did the aircraft crash? Because one of its motors came loose. In all three cases, the explanation is supposed to yield knowledge. Concerning the why-questions, however, not all are requests for an explanation and, thus, not every answer to a why-question yields knowledge. Some why-questions express the wish to find consolation (Why have you abandoned me?) or the wish to get rid of prejudices (Why should men and women not get the same salary for the same job?). In the science and religion discussion it is intensely debated whether religious answers to such a question as "Why is the universe so special and finely tuned for life?" are explanations, yielding knowledge, or whether they have other functions in the believer's life.

The covering law model

Quite often explanations of why something is the case are related to causation. Other explanations are functional or teleological, as they are also called. The white fur of the polar bear is explained by its camouflage function. A common view is that those explanations actually are causal explanations referring to past causes in evolution that led to the natural selection of the biological trait in question. Causal and functional or teleological explanations are seen as two different variants of the so-called covering law model.

According to the covering law model, an explanation of an event consists in subsuming it under a causal law: All metals expand when heated; this rod is metallic and it was heated; therefore, it expanded. There are four conditions for such a scientific explanation:

(1) The *explanandum* (The rod has expanded.) has to follow logically from the *explanans* (All metals expand when heated; this rod is metallic and it was heated.). Only if the explanandum can be deduced from the initial circumstances and the applied causal laws, the explanandum is really explained and justifies the prediction of a similar event, even if it has not been observed yet.

(2) The applied causal laws (All metals expand when heated.) have to be laws proper and not only all-statements. It is not an explanation to say: "All apples in this basket are red; this apple is from the basket; therefore, the apple is red."

(3) The explanans needs to have empirical content; it should be possible, at least in principle, to confirm or falsify the explanans through experience. Without this condition explanations like God's wrath as the cause of historical catastrophes could not be excluded from science.

(4) The explanans has to be true. If it were false, the implication between the explanans and any explanandum would be true for logical reasons and the explanandum would not be explained.

Although the covering law model cannot be applied everywhere in its strict form, it is supposed to represent an ideal that at least all explanations in the natural sciences that are answers to why-questions ought to strive to attain. It satisfies one feature that one would expect of such explanations, namely, that it explain why a certain event occurred and not another. By subsuming an event under causal laws, it is shown that the event had to occur. The price to be paid for this is determinism, excluding the possibility of exceptions. One way of coping with this difficulty is to allow deterministic as well as nondeterministic explanations. Thus, the explanation of a patient's death from lung cancer may take the form of a statistical explanation referring to the frequency of dying from lung cancer and smoking heavily. According to this variant of the covering law model, the explanandum is not deduced from the explanans. It is supposed to follow with an inductive probability. The reference is not to exceptionless laws but to statistical regularities concerning events and to tendencies concerning human actions.

Rational reconstruction

Another model of explanation that is supposed to be an alternative to the covering law model in, for instance, historical research consists in explaining an event as the result of human action by rational reconstruction. First, an event is shown to be an intentional act that the agent in question has undertaken in accordance with beliefs that seemed reasonable in the situation at issue. Second, the critical examination of the agent's beliefs, whether true or reasonable, contributes to explain why the action resulted in precisely that event. So, in some historical cases, the fact that the belief in the enemy's strength was false may explain why the army was defeated in a certain battle.

Explanation in the science-religion dialogue

One frequently discussed question in theology and in philosophy of religion concerns the relationship between scientific and religious explanations: whether they are on the same categorical level or belong to completely different domains. The difference between scientific and religious explanations is sometimes identified by pointing out that science causes questions that go beyond its own power to answer, for instance, the question "Why is the universe so special and finely tuned for life?" Since this question is not a question formed within science, it cannot be answered scientifically. Instead, the question is a metaphysical why-question, wherefore it can be answered, for instance, theistically by saying "because the universe is created by God who wills that it be so." Since it is not always clear to what extent cosmological theories about the beginning of the universe are metaphysically laden, it is also not clear to what extent the theistic answer competes with scientific explanations or with the metaphysical aspects of some of these theories.

See also CAUSALITY, PRIMARY AND SECONDARY; CAUSATION

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EXTINCTION

See EVOLUTION

EXTRATERRESTRIAL LIFE

The concept of extraterrestrial life, embodied in the discipline known as exobiology, astrobiology, or bioastronomy, is one of the oldest in the history of science. Although the search for life beyond Earth has always been intrinsically difficult, and intermingled with philosophy and theology, it has usually been a reflection of the science of its times.

The idea of an infinite number of worlds was part of the ancient Greek atomist system, but was opposed by the physical principles of the philosopher Aristotle. Beginning in the sixteenth century, Copernican theory made the Earth a planet, and the other planets potential Earths. In the seventeenth and eighteenth centuries, Cartesian cosmology extended the idea to other planetary systems, as did Newtonian cosmology, at first in conjunction with natural theology and later with the nebular hypothesis. Only in the twentieth century, and especially with the space age, has empiricism become a major component of the search for extraterrestrial life. It has done so under the banner of cosmic evolution, the idea that the universe has evolved from the Big

Bang to planets, stars, galaxies, life, and intelligence. Although at the limits of science, the question of the abundance of life in the universe has been passionately pursued because it bears so strongly on humanity's place in the universe. As such, "the biological universe," as it has been called, has generated considerable and ever increasing theological and philosophical discussion.

Research on extraterrestrial life

Research on extraterrestrial life is pursued in at least four areas: planetary science, planetary systems science, origins of life studies, and the Search for Extraterrestrial Intelligence (SETI). Not surprisingly, the planet Mars was the focus for much of the twentieth century, beginning with the canals of Mars controversy and culminating with the Viking missions in 1976. The latter demonstrated to the satisfaction of most scientists that no organic molecules were present on the surface of Mars at the Viking lander sites, samples of which were analyzed down to parts per billion. Surprisingly, the problem of life on Mars was again highlighted in 1996 when scientists at NASA announced possible fossils in an ancient Mars rock found in the Antarctic. This conclusion caused an uproar and is still hotly debated. Meanwhile, the discovery of a possible liquid ocean under the ice of the Jovian moon Europa raised the unexpected possibility of life in the solar system beyond the ecosphere usually considered hospitable for life.

Although Earth-like conditions have not been found elsewhere in the solar system, extrasolar planets provide potential abodes of life. After a long and fruitless search during most of the twentieth century, in 1995 the first planet was found around the solar-type star 51 Pegasi. In the following six years, with increasingly refined technology, more than eighty planets were found around sun-like stars within a few hundred light years of Earth. More are being discovered monthly. The evidence is indirect, and the planets discovered through 2001 are gas giants like Jupiter, many in highly eccentric orbits or very close to their parent stars. The search continues for Earth-size planets, and the technology is advancing to the point where their detection may be possible within the next decade.

Because there is no guarantee that life will arise even on Earth-like planets, an understanding of the mechanisms of the origin of life is essential. Unfortunately, these mechanisms are not well understood, even on Earth. Nevertheless, the discovery of life in extreme environments—inside rocks, several kilometers below the surface of the Earth, and deep in the ocean—indicates that extraterrestrial life might develop under conditions considerably broader than thought possible. In particular, the exploration of deep-sea hydrothermal vents and their associated life, including tube worms several meters in length, has provided insights into the limits of life, and even the possible origin of life on Earth. Delivery of organic materials, and even life, from beyond the Earth remains an alternative possibility for the origin of life.

SETI programs seek artificial signals emanating from planets around sun-like stars, using a variety of assumptions about signal frequency and targets. For forty years, beginning with Frank Drake's Project Ozma in 1960, SETI relied mainly on radio telescope technology. During the 1990s, the search began expanding to include optical techniques, even as dedicated facilities were being built and increasingly complex software constructed for signal detection. While there have been some false alarms, no unambiguous signals from extraterrestrial intelligence have been detected. In fact, aside from the controversial Mars rock, no form of extraterrestrial life has yet been discovered.

Implications for religion and humanity

The human implications of the existence of extraterrestrial life have almost always been discussed in terms of extraterrestrial intelligence. For centuries religious implications have been a center of attention, especially in the Christian context, beginning with medieval commentaries on Aristotle and increasing significantly in the wake of heliocentrism. In the post-Newtonian era, scriptural objections were largely met by demonstrations of the benefits of extraterrestrials to natural theology, in which a universe full of life was seen as a demonstration of God's omnipotence and the magnificence of divine creation. During the nineteenth century, in the absence of techniques to resolve the scientific question of life on other worlds, the religious implications were explored in considerable detail. Three options were considered and adopted: religion and extraterrestrial life could be reconciled, certain religious doctrines could be rejected, or the idea of inhabited worlds could be rejected. No consensus has been reached on these options. Nor is there consensus on the effect of the discovery of extraterrestrials on Christian thought, particularly the doctrines of redemption, incarnation, and salvation. A few religions, including Mormonism, have incorporated the concept of life on other worlds into their religious doctrine. The implications for non-Western religions have only begun to be explored, but in general it seems that the effect on non-Adamist religions would be less than on those that teach salvation through a single God-head.

In a broader sense, the biological universe may be seen as a worldview analogous to the Copernican and Darwinian worldviews. It is possible that the implications for humanity will be similarly widespread, and may follow the general outlines of the reception of past world views, for which there is a rich literature in the history of science. Science fiction, both literature and film, has also addressed the human implications. In particular the work of Olaf Stapledon, Arthur C. Clarke, Stanislaw Lem, Carl Sagan, and Maria Dorrit Russell, have treated the theme of alien life in a thoughtful manner.

Finally, extraterrestrial intelligence may relegate all human knowledge to the status of a specific instance of a more general knowledge possessed, and perhaps shared, by civilizations scattered throughout the universe. On the other hand, in the absence of extraterrestrial intelligence, human destiny may be to spread throughout the galaxy on some variation of the model adopted in Isaac Asimov's *Foundation* series of novels, as opposed to the complex interactions with extraterrestrials found in Clarke's work. Either way, the implications are sobering.

See also EXOBIOLOGY; SCIENCE FICTION

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F

FAITH

Faith as the heart of religious adherence is chiefly a Christian concept and a matter of Christian self description that has been used in the West to describe not only Christianity but other religions as well. In many other religions there are strong analogies to the Christian concept of faith, but they are still by and large analogies. Thus, this entry will deal with the Christian concept of faith and only analogously with other religions.

Definition

Faith would appear to be one of the chief problems in the relations between science and religion. Not only do Christians believe certain things that appear to conflict with scientific accounts of the world, and that are in principle inaccessible to scientific method, it is a theological virtue and necessity to believe them. To believe certain things about God (*credere Deo*) is to believe them because one believes God (*credere Deum*) (i.e., because one believes what God says and reveals because God is God); and one is willing to do that because one believes or trusts in God (*credere in Deo*). This is according to the definition of Augustine of Hippo (354–430), reiterated by Thomas Aquinas (c. 1225–1274). According to them, it is this sort of faith, never mere belief, that defines a Christian. As Augustine observed, the devil believes the same things as the saint but cannot, of course, be considered to have faith because the devil does not trust in God. The reformers Martin Luther (1483–1546) and John Calvin (1509–1564) did not use this same formula; both, however, insisted that Christian faith always involved an inner element of trust and assurance. Never was it mere belief of facts or propositions.

Explanation or virtue?

This way of stating the problem, by stressing the inner aspect of faith, has not always been emphasized in debates over faith since the Enlightenment. Beginning with John Locke (1632–1704), who certainly had the ground prepared for him by others, and continuing through David Hume (1711–1776), philosophical and even theological concern with the concept of faith has largely been, with a few exceptions such as Søren Kierkegaard (1813–1855) and John Henry Newman (1801–1890), over what is believed. Such a perspective assumes that religious beliefs are formed in much the same way as scientific beliefs or that religious beliefs answer to the same sort of inquiries as scientific beliefs. In this case, religion is assumed from the outset to be an explanation for, say, how the world came to be; as such it competes directly with scientific accounts. It can then be assessed on the same methodological bases as scientific accounts. Locke, for example, thought Christian beliefs were credible because, he argued, one could (1) demonstrate that God exists and (2) have reason to believe what God had revealed whenever the propositions proposed for belief were attended by miracles, which served as evidence of their divine origin. Once one had such good reasons for belief, one could give one's will to propositions about God. Hume did not dispute this approach; he simply argued that one cannot demonstrate the existence of God and that miracles, though possible in principle, were never actually believable because they were, by definition, violations of what is normal. Thus, he argued, one should always be skeptical about miracles and reports about miracles.

Although Christians, on the Augustinian understanding, certainly confessed numerous objective beliefs about God, it was the inner virtue of trust that was paramount; trust was always prior to belief, and always linked to it. For Locke and Hume and the philosophical tradition after them, however, the relation between outer confession and inner trust is reversed: One ought not to give one's assent to God until the evidence dictates it. Even then, faith should be proportioned to the degree of certitude possessed by the evidence. Whether faith that is formed by certain or even highly probable chains of reason is actually faith is, of course, disputable, for there is no special personal virtue in committing oneself this way. Neither is there anything to be discovered by faith since the assent depends entirely on external evidence, accessible in principle to anyone who does not have faith.

On this account, then, faith and science would be comparable. Both are seen as explanations, and both depend on comparable sorts of evidence, giving answers to the same sort of inquiries. For example, religion and God might be considered explanations upon inquiry by early human ancestors into "how we got here." If primitive people were concerned by human and cosmic contingency and felt the need to explain it, so too are modern people, but they have much higher standards, such as the ones that Locke and Hume proposed. Or so the argument goes.

However, neither Jews nor early Christians actually seemed much given to this sort of speculation about cosmic origins. Rather, they conceived of their relations with God in much more personal categories. Since their relations with God were personlike, they required personal sorts of concepts for discussing matters about God, and such concepts require certain personal virtues, such as openness, loyalty, truthfulness, and love. These factors are central in the Augustinian definition of faith, where what is believed is important, but what is more important is the inner, personal nature of faith. In Christianity this inner aspect of faith was never meant to be static; faith was considered to develop and transform the believer through the exercise of the personal virtues. According to the biblical witness, this is a transformation whereby a person in faith is "in Christ" and Christ is in the believer. Faith is thus theologically never a set of beliefs *simpliciter* about God and Jesus Christ; it is the very means by which God dwells in the lives of the faithful. It is important to recognize that much of what is believed about God, as in the analogous case of believing things about other human beings, can only be discerned by those whose developing life in faith equips them with the proper sensibilities. These sensibilities rarely include the epistemic distance and methodological indifference that scientific inquiry requires. These sensibilities require the thinker to put his or her own thoughts into question.

A holistic approach to faith

To approach faith in this way can cause one to reconceive many (but not all) of the problems commonly thought to exist between science and religion. If the heart of faith is a personal openness and an ongoing moral and spiritual transformation of the thinker, then there is a certain shift in the weight given to faith's "what is believed" when one considers the relations between science and religion. To be sure, the objective beliefs of faith are never irrelevant to faith; nevertheless, if the thinker who holds them is in the process of transformation, surely what is believed is continually subject to ongoing interpretation. Any literalism that suggests that a human thinker enjoys a God's-eye view is not tenable. Furthermore, insofar as faith stretches itself to see the world as God created it and seeks to reproduce itself through the rational teaching of others, it is not innately unscientific, unmethodical, dogmatic, or credulous. It can invite method, freedom of opinion, and critical judgement. Barring therefore any definitive reductionism by science, discussion between faith and what science proposes may always be open ended.

In addition, many of the personal habits and dispositions required for faith may contribute to the personal habits and dispositions needed by scientists who want to do cooperative research with intellectual integrity. Insofar as faith requires deep self-reflection on the moral stance of the thinker and on the purposes of human knowledge gained by research, and insofar as it causes the scientific questioner to put him or herself into question, it may even cause one to look at how science contributes or does not contribute to overall human flourishing, including aesthetic, moral, and spiritual flourishing, since science is a function of beings for whom these things are vital.

If, however, approaching faith in this Augustinian way lessens the need for direct confrontation with science over one's specific beliefs about the world, it also raises what may be a deeper problem, namely, the difference in the way faith and scientific method think and imagine. Newman suggested that if faith's appeal to the human mind should ever be overcome, it will not be because faith has been out-reasoned, but because the human mind has lost the ability to imagine itself approaching the world by any method other than the scientific, and because it must always provide explanations of the sort provided by science, for which a distanced and impersonal approach is required. This would result, in the poet T. S. Eliot's phrase, in a "dissociation of sensibility" whereby faith's native imaginative means and sensibilities for dealing with the world and human life are replaced with other incommensurate sensibilities, thus effectively overcoming faith.

See also ATHEISM; CHRISTIANITY; SPIRITUALITY

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FAITH HEALING

See SPIRITUALITY; SPIRITUALITY AND FAITH HEALING

FALL

According to the theology of the early Christian church fathers, Adam not only possessed complete human harmony, he also possessed an encompassing knowledge of nature such that God brought all the animals to him so that he could name them (Gen. 2: 19–20). Adam and Eve lost not only these gifts as a result of the fall, but suffering and death became part of their lives and were passed on to their offspring. Eastern theologians, therefore, spoke of death by heredity, while Augustine of Hippo and other early Western theologians spoke of original sin that is passed on by heredity from one generation to the next. According to this view, only the Bible, as God's revelation, offers true knowledge.

During the Middle Ages, the influences of the theologies of creation and Christology, as well as the reception of Aristotelian and other ancient Greek writings, brought about a new understanding of the regularity and independence of the laws of nature. Scholars began to see nature as a second book of God's revelation, in addition to the Bible. Consequently, the idea appeared that humans had to study the book of nature to regain partly the knowledge that Adam had lost in the fall. This idea was important in English physico-theology during the sixteenth and seventeenth centuries, which strongly influenced the emerging natural sciences.

Criticism against the doctrine of original sin emerged with Enlightenment philosophy, which, contrary to the natural sciences and their conception of deterministic laws, emphasized human freedom and deemed the conception of passing on sin by heredity a confusion of categories in which sin was an aspect of history, and heredity an aspect of nature. Enlightenment philosophy interpreted the fall as a necessary step in human development from a dreaming, childlike consciousness toward the full adult consciousness that befitted humanity. For nineteenth-century philosopher Søren Kierkegaard, angst, which distinguishes humans as ecstatic beings from animals, is the actual occasion for sin. Kierkegaard rejects, however, any attempt to scientifically construe a cause for sin because this would create only myths.

The theory of evolution challenged the traditional doctrine of original sin from still another angle. How could primordial humans, who hardly differed in their abilities from animals, have had a comprehensive knowledge of nature, and how could they have determined the whole of human history that was to come? Evolutionary theory also weakens arguments against the doctrine of original sin that stem from Enlightenment philosophy. Evolutionary theory, in effect, transcends the juxtaposition of nature and history that the Enlightenment had assumed because it can show how behavior is, in fact, passed on through heredity, and contingent (historical) events can become structural elements of a living organism.

The doctrine of the fall, on the one hand, intends to emphasize that evil, which has been the cause of great suffering in the course of history, is rooted deep within humanity, and therefore is not easily overcome. It rejects all simplified, quick, and utopian solutions to the problem of evil. On the other hand, the doctrine precludes human nature from being identified with evil, and thus leaves the way open for potential, however laborious, progress. It addresses a depth in the human person that can only be addressed in a language of its own, such as myth.

Furthermore, evolutionary theory explains how events and developments that are experienced as negative or evil by single creatures (e.g., suffering, being killed, being fed on) are conducive to the development of life in general. In this way, evolutionary theory provides a new context for theological reinterpretations of the traditional doctrine of the fall. These reinterpretations are developed within the framework of either classical theology (Raymund Schwager), process theology (Jerry Korsmeyer), or as part of a common theory of religions (Eugen Drewermann and Philip Hefner).

See also AUGUSTINE; EVIL AND SUFFERING; EVOLUTION; HUMAN NATURE, RELIGIOUS AND PHILOSOPHICAL ASPECTS; NATURAL THEOLOGY; TWO BOOKS

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FALLIBILISM

Fallibilism is the view that human knowledge lacks a secure and an infallible foundation. Fallibilism is associated in particular with American scientist and philosopher Charles S. Peirce (1839–1914) and Austrian-born philosopher Karl Popper (1902–1994). In its most comprehensive form the fallibilist maintains that people cannot know anything with certainty. In its more restricted forms uncertainty is attributed to a particular domain of beliefs, such as empirical or religious beliefs. What separates fallibilists from others is the confidence each gives to epistemological success in general or within a particular domain. Participants within the science/religion discussion quite frequently affirm fallibilism. Its merit seems to be that it opens up possibilities for a dialogue on more even terms than foundationalism does.

See also FALSIFIABILITY; POSTFOUNDATIONALISM

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FALSIFIABILITY

In opposition to the verification criterion of the logical positivists, Austrian-born philosopher Karl Popper (1902–1994) defended the idea of falsifiability. According to Popper's falsification criterion scientists should develop theories that can be falsified by observation. They should then try to falsify them, and those that survive testing should then be tentatively accepted and regarded as corroborated, that is, as closer to the truth than theories that have been falsified. The criterion was intended to demarcate science from pseudo-science. In the mid-twentieth century these ideas and their consequences for religious beliefs were at the center of the science/religion debate, but because of doubts about whether science itself could satisfy Popper's requirements, issues of falsifiability have had a less prominent place in the debate since the 1980s.

See also FALLIBILISM; POSITIVISM, LOGICAL

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FEMINISMS AND SCIENCE

At their most basic level, feminist perspectives on science begin with the observation that women have been excluded from the practice of science. This exclusion has sometimes been overt. For example, women have often been barred from getting the education required to become scientists. Overall, feminists have demonstrated that, for women, it is difficult to get in, difficult to stay in, and difficult to advance to positions with the power to control the direction of scientific study. Exclusion has also been more covert, as demonstrated by the lack of women's perspectives within science.

Feminists argue that a number of problems are related to this exclusion, including depletion of natural resources, tainted food sources, pollution, and impending viral disaster. They argue for a number of different causes and solutions for this exclusion of women—some compatible, some conflicting—which makes it more proper to speak of "feminisms" and science, rather than feminism. Despite these differences—or, perhaps, because of them—feminist perspectives remain a rich resource for understanding science and for rethinking the relationship between science and religion.

Margaret Wertheim, for example, in her book *Pythagoras' Trousers: God, Physics, and the Gender Wars* (1995) argues that there is a connection between the exclusion of women in physics and the exclusion of women from positions of authority in Western religion. From the mystic Pythagoras, to the revival of physics in medieval monasteries, to Albert Einstein's observation that "in this materialistic age of ours, the serious scientific workers are the only truly profoundly religious people," physics has been permeated with a religious sensibility. Wertheim explores how women have been excluded both from the right to interpret Scripture and from the right to interpret God's other revelation, nature.

Feminists have examined the diverse ways that women have been excluded from science and how male perspectives and bias have influenced the selection of problems to examine and decisions about how to organize and interpret data. What these arguments have in common is that the problem is seen as external: The results may be biased, but that bias is unrelated to the basic methods and assumptions of science. In fact, bias occurs because exclusion of women leads to a distortion of proper scientific method. These eternal explanations lead to external solutions: Remove the barriers for women in science; get them in and get them into positions where they can influence the direction, programs, and interests of science. Wertheim, for example, argues that women should be involved in physics in order to influence the direction of the research and to create a new culture of physics.

From this perspective, there is no such thing as "women's science," except to the extent that women may choose different problems to address or, perhaps, organize data differently. Including more women will bring about a better science, truer to its ideals and goals, but it will not bring about a different science.

Internalist arguments

Some feminists see this as a partial solution. Post-Kuhnian philosophies of science suggest that scientific concepts, theories, methodologies, and truths are not objective, but instead bear the marks of their collective and individual creators. The social location of the scientist not only influences the direction of science, it can influence the shape of science itself and even the truths it discovers. Feminists focused on gender as one of the aspects of culture that shape science.

All cultures sort human beings by sex, but there are variations in the roles, duties, characteristics, and so on that define those divisions. These variations are what is meant by *gender.* Feminists have argued that in the West, science is constructed around gendered assumptions, with "male" categories privileged over "female." It is not just the centrality of "rational man" that is problematic, but that what counts as rational or objective is that which has been given a masculine meaning.

Women have demonstrated this connection between gender and science in a number of ways. One of the most influential works in this regard is Carolyn Merchant's, *Death of Nature: Women, Ecology, and the Scientific Revolution* (1976). Merchant argues that prior to the sixteenth century, nature was seen as female: a mother, a lover, and so on. Further, nature was seen as a living, dynamic entity with a body and a soul. This conception carried with it an ethic towards nature that was marked by moderation. If one abused or exploited nature, one faced the consequences.

In the 150 years from Nicolaus Copernicus to Isaac Newton, this view completely changed. Nature became a machine, made up of discrete, interchangeable parts. Because nature was no longer alive, with no spirit and no animation, it could be exploited at will. This change had a religious dimension. Merchant, Rosemary Reuther, Evelyn Fox Keller, and others have argued that the scientific revolution was a child of the Reformation in that the removal of the divine presence from within nature contributed to the transformation from nature as mother to nature as machine. There was a further connection in that the Fall of Genesis was seen as both a fall from innocence and a fall from dominion. Innocence could be regained through religion, dominion through science (*techne*).

This change was, of course, gradual, but it was not always subtle, especially in its use of gendered language. Women and nature were connected: Women threatened man's innocence; nature threatened his dominion. And, just as God intended that man should dominate and control woman, God intended that man should dominate and control nature. In the early seventeenth century, Francis Bacon encouraged scientific endeavor by declaring that nature, like a woman, locked her secrets away in her womb. But, like a women, she wanted to be penetrated and her secrets taken. The male scientist should extract the truth by force, and thereby command nature and compel her to serve him.

These insights have been influential in the development of ecofeminist thought, as well as feminist philosophies of science. They suggest that the problems with science are not external; rather, its epistemological assumptions and methodologies are themselves biased. The problem is not bad science, the problem is science itself. Unlike internal approaches that seek to get women into labs, these feminists insist that it is necessary to transform science, to promote a different science based on a feminist epistemology.

Feminist epistemologies and feminist science

Feminists have offered several alternatives to existing "masculinist science." Feminist empiricists, such as Helen Longino, have sought to integrate feminist concerns with existing empiricist assumptions, arguing that the social identity of the observer is not irrelevant to the practice of science. Instead, values are imbedded in science, and scientists should therefore be intentional about which values they bring to their work. Feminist empiricists have been criticized for retaining certain aspects of empiricism: the primacy of reason, the centrality of the (experiencing) individual, and the separation between public and private in science. Further, feminist empiricists do not challenge the assumption that there is but one science and one nature waiting to be discovered by it.

As an alternative, feminists such as Sandra Harding have argued in favor of *standpoint theory.* This arises out of German philosopher Georg Wilhelm Friedrich Hegel's (1770–1831) dialectic between master and slave, and the observation that the standpoint of the slave offers a more complete, less distorted view of the world. The master thinks that the slave responds only to the master's commands. The slave knows that the slave also dreams, intentionally thwarts the master's plans, reads in secret, and even plots rebellion. In other words, the master only knows one reality, but the slave knows there are more. Feminist standpoint theorists suggest that starting from—or at least including—women's perspectives on and experiences of the world can give science a more comprehensive and reliable view of the world.

A third position, *feminist postmodernism,* begins with the observation that there is no single standpoint. Donna Haraway, for example, links women's experiences with the experiences of other "others," such as African Americans. Just as contemporary science blurs boundaries between human and animal, organism and machine, physical and nonphysical, this approach blurs boundaries between standpoints and embraces the partiality of a feminist point of view—indeed any view—and the possibilities that partiality opens up.

Despite their differences, these positions converge on the point that there is something essentially wrong with the way that science is done, and they argue for a "feminist science." This does not mean that feminist epistemologies should be equated with relativism; few if any feminist philosophers of science would take an antirational or anti-objective stance. Most would argue that feminism is a way to increase the objectivity of science, although it is an objectivity that is not grounded in the detached observer.

Feminist rationality is a responsive rationality, what Hilary Rose refers to as "thinking from caring" and what Evelyn Fox Keller sees as knowledge arising from a relationship between knower and known. This knowledge does not require, and in fact rejects, distance between the observer and the observed. Nature is not a "thing," separate or separable from a speaking and knowing "we." What people know about nature they know because they interact with and are embedded in it. People know the world, because they are a part of the world and because they are in a relationship with it.

In addition, feminists argue that it is not subjectivity—the context and desires of the observer—that leads to bad science, but the illusion of objectivity. Values do not distort science; it is only coercive values—racism, classism, sexism—that threaten objectivity. Participatory values decrease rather than increase distortions, so objectivity is enhanced when people are intentional about their subjective preferences and can choose those that are most effective. Feminists have gone so far as to suggest that these participatory values are the preconditions of objectivity.

Multicultural and global feminisms

An additional feminist approach is emerging in the recent writings of Sandra Harding, where she explores the intersection of post-Kuhnian, feminist, and postcolonial science and technology studies. Just as feminists argue that feminist science involves more than bringing women into laboratories, multicultural approaches require more than just tacking on issues of women of color. The frameworks set by Western women can themselves block concerns from other perspectives, and alternative frameworks give way to different institutional contexts and different concepts. For example, Western science thinks in terms of nature, which is distinct from the human being, while in developing countries the focus is on the environment, which is something with which human beings interact.

The issue is not whether knowledge is universal, or whether the law of gravity is the same everywhere. The question is whether there is one best way to represent the world. Women's science is problematic to the extent that, like men's science, it retains the view that there is *a* science.

Each culture is a tool box containing different resources for understanding nature. Because different cultures are exposed to different parts of nature, they develop distinctive resources. In addition, each culture has distinctive metaphors, models, and languages that enable them to see their particular parts of the world in diverse ways. These resources generate both systematic knowledge and systematic ignorance about nature.

If people settle on one "science," these diverse ways of organizing and producing systematic knowledge will be lost, reducing knowledge of the world. Diverse perspectives not only allow people to see more, they enable people to see better, promoting a more rigorous objectivity by revealing aspects of nature that may be difficult or even impossible to detect from within the dominant culture and perspective. In the same way that the world needs biodiversity to continue to renew itself, so too does knowledge of the world need different sciences to maintain its creativity.

What is needed is what Sandra Harding calls a *borderlands epistemology* that values the distinctive understandings of nature that different cultures generate. The goal is not to integrate them into an ideal knowledge system, because that would necessarily sacrifice the advantages of the differing conceptual schemes that different cultures have developed. Instead of a single science, scientists would learn when to use one science and when to use another, what to value in modern sciences and what to value in other knowledge systems. What they would learn is which approaches provide the best set of maps for each particular journey.

See also ECOFEMINISM; ETHNICITY; FEMINIST COSMOLOGY; FEMINIST THEOLOGY; LIBERATION THEOLOGY; WOMANIST THEOLOGY

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FEMINIST COSMOLOGY

Feminist cosmology is both a critical and constructive model of the cosmos. Feminists criticize the mechanistic, dualistic, patriarchal model of the cosmos informed by Enlightenment philosophy and modern science. This dominant model creates hierarchical dualisms: human over nature, mind over body, male over female, subject over object. The subjugation of nature is linked to the subjugation of women. Feminist cosmologies restructure these pairs, like nature and humans, as intimately and interdependently related to each other in a web of moral responsibility. Ecofeminists lead the charge in developing a cosmology that not only reconstructs a new world view, but also calls for radical change in the way that humans live with the natural world.

See also COSMOLOGY, RELIGIOUS AND PHILOSOPHICAL ASPECTS; ECOFEMINISM; FEMINISMS AND SCIENCE; FEMINIST THEOLOGY; WOMANIST THEOLOGY

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ANN PEDERSON

FEMINIST THEOLOGY

Feminist theology emerged from the notion that Christian theology and the institutional embodiment of Christianity not only excluded women's voices and experiences, but also developed practices that are sexist, patriarchal, and androcentric. Contemporary feminist theology finds its historical roots with those who question authors of sacred texts and those who challenge theologians who defined what it meant to be a human being from the perspective of patriarchal, male experience. For centuries, male experience was the standard by which the worth and contribution of women was judged. In the 1960s, contemporary feminist theologians began to challenge and protest these fundamental doctrines and practices of institutional Christianity.

Feminist theology is not limited to the Christian tradition. Jewish and Islamic feminist theologians also examine the patriarchal assumptions that support the subordination and oppression of women. Judith Plaskow, for example, calls for a retrieval and redefinition of the past in order for women to reform Torah; Jewish women must rewrite texts, author new liturgies, and disclose voices from the past. Islamic feminist theologians, such as Riffat Hassan, speak not only about patriarchy, but also about mixing modernization and Westernization with Islam. These are two examples of the growing diversity of feminist voices in theology. While feminist theologians come from diverse cultural and religious traditions, they share similar hopes and common interests.

Methodologies and types

Feminist theologians employ similar methodological strategies that result in substantive, constructive changes within Christian theology and practice. Three important steps must follow. First, feminist theologians reflect critically on the patriarchal and androcentric nature of the churches' practices and theological doctrines. This critical step challenges the values and theological paradigms that support patriarchy. For example, Sallie McFague (b. 1933), a European-American ecofeminist theologian, challenges the patriarchal model of God and the world as one that sanctions and supports an understanding of divine power and human power that dominates and excludes women. Second, feminist theologians return to the tradition to delve deeper and discover voices that have been previously ignored and discarded. These acts of retrieval expand and deepen the liberatory voices already within the tradition. Third, many feminist theologians begin the process of reconstructing theological doctrines with new paradigms. McFague utilizes the metaphor of the body of God to reconstruct the relationship between God and the world. This paradigmatic shift emphasizes mutual and reciprocal relationships between God and the world instead of hierarchical and dominating ones.

Generally, three types of feminist theology have developed in their relationship to Christianity. First, some feminist theologians seek modest changes in the traditions from within Christianity. For the most part, these theologians are less critical of the structure of Christianity. Other feminist theologians, while still working from within a Christian framework, seek not only to critique the theology, but also to reimagine and reconstruct new models of thinking about and practicing Christianity. Radical transformation of both doctrines and the institutional practices of Christianity is sought. Another category of revolutionary feminist theologians find the nature of Christianity so thoroughly patriarchal, that their only way to remain committed to feminist concerns is to leave Christianity. These voices can be described as post-Christian.

The first phase of feminist theology concentrated primarily on issues related to gender. Later, the development of feminist theology from a white, privileged standpoint began to embrace and connect with other women's voices and experiences. In fact, the category of women's experience, while embraced early on in feminist theology, has become problematic since it so often only seemed to describe the experience of one voice: that of privileged, white women. Feminist theologians were primarily white, privileged women working within the confines of the academy. As feminist theologians linked their projects to other liberation movements, the challenge was to examine their own bias of class and race. Feminist theologians began to question the category of "women's experience." There is no monolithic experience, no single way of being women. Feminist theology consequently linked the voices and experiences of those excluded because of race, class, sexual orientation, disability, age, and gender. Consequently, feminist theologians are now a worldwide company of voices, having expanded from American white feminists to Asian feminists, Womanists, Mujerista theologians, and many others. Feminist theology continues to expand upon and celebrate the variety of voices and experiences. Tensions and dissonances that reside in these differences are opportunities for creative new theological explorations.

Links with science and ethics

Feminist theology is also linked to other feminist projects in fields like science and bioethics. For example, in religion and science, feminists are critical of the patriarchal systems in which both disciplines are embedded. Science, like religion, is a socially-situated institution that has excluded women from its theory and practice. Contemporary feminist philosophers of science are linked to feminist theologians in their common critique of the Enlightenment ways of knowing the world (epistemologies) and their institutional embodiment, which support patriarchal and androcentric viewpoints. Feminists are critical of the convergence of modern science with the modern or Enlightenment worldview because it excludes women as valuable knowers and participants in the scientific process. Feminist philosophers of science criticize the Enlightenment epistemology that sees those "in the know" as impartial, detached, impersonal, value-free, and dispassionate.

Similarly, feminist philosophers of science have different ways of critiquing science. Sandra Harding examines three different kinds of feminist scientists. First, feminist empiricists uncover sexist and androcentric biases in the sciences. The addition of more women in the institution of science might be enough of a corrective. Feminist empiricists, like the reformist feminist theologians, don't directly link science to politics. Both groups are less critical of the institutions themselves. Second, feminist standpoint theorists claim that knowledge grounded in the perspectives and experiences of women's lives is actually a more comprehensive, objective way of knowing. They criticize the dominant standpoint of patriarchal science. Much like the revisionist theologians, they insist that research and data collection must begin with voices that have been systematically excluded. Finally, feminist postmodernists reject the foundationalism of modern epistemologies and sciences, calling for a new science. This position is similar to the post-Christian feminist theologians who reject Christianity itself and call for new ways of expressing spirituality. Both feminist theology and feminist philosophers of science require narratives of those who have been marginalized. They both require beginning the research, data collecting, and questions from the perspectives of the voices of "the other."

In both religion and science, feminists insist that epistemology and ethics are inextricably linked together: People are accountable for what they do with what they know. Substance and praxis follow together. Feminist research develops postmodern epistemologies that value multidimensional perspectives to expand and widen the definition of reason, begins research with the excluded voices, and constructs the subject/object relationship on the same epistemological plane. Feminist research becomes a model for research and living: Multiple voices are used for research, and conversational praxis is the methodological means of including voices of those formerly excluded. In the field of religion and science, the research program of Anne Foerst in artificial intelligence and theology constructs an embodied theology and epistemology that redefines what it means to be human. The theology of Nancy Howell explores how the subjugation of women and nature is interconnected. Her ecofeminist theology offers new ways of constructing models of God and the world. These are two examples of the constructive feminist engagement between religion and science.

See also ECOFEMINISM; ECOLOGY, ETHICS OF; ECOTHEOLOGY; EPISTEMOLOGY; FEMINISMS AND SCIENCE; FEMINIST COSMOLOGY; LIBERATION

THEOLOGY; POSTFOUNDATIONALISM; POSTMODERNISM; WOMANIST THEOLOGY

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FIELD

The term *field* designates a variety of different, closely related concepts in mathematics and physics that have been carried over into everyday language to designate a context or region of influence. In geometry a field is a function that is defined (i.e., has values) at every point of a manifold (smooth continuous surface). Similarly, in physics a field (e.g., an electric, magnetic, or gravitational field) is a function describing a physical quantity (e.g., electric, magnetic, or gravitational influence or forces) at all points of a region of space and time. Sometimes the region that is under the influence of an electric, magnetic, gravitational, or other source or agent is also referred to as a field. A similar and almost equivalent definition of a field in physics, especially in contemporary physics, is as a continuous dynamical system, or a dynamical system with infinite degrees of freedom. Fields are essential to the description of physical phenomena, particularly of the interaction between particles or other physical entities, and to the quantitative and qualitative modeling of forces, especially those that act at a distance without any medium.

See also FIELD THEORIES; GRAVITATION; PHYSICS, QUANTUM

WILLIAM R. STOEGER

FIELD THEORIES

Most of classical and quantum physical phenomena are fundamentally described and explained in terms of fields, such as the electromagnetic and gravitational fields. These physical entities are not localized objects or particles, they generally vary in time, and they are defined at every point in space. They represent the influence, or force, an object or particle would experience at each point in space, at the time indicated. These fields are represented mathematically by functions of space and time. Field theories are the systematic theoretical mathematical-physical descriptions and elaborations of these fields, including their generation, detection, behavior, and relationships with one another and with other physical entities, such as particles. Generally, field theories are expressed in terms of partial differential equations that describe the relation of the fields to the entities that cause, or source, the fields.

There are also energy and momentum conservation equations that further constrain the fields, as well as the closely related equations of motion, which describe how particles or objects move at every point under the influence of the fields. All of these equations are generally derivable from a very special function, called a *Lagrangian,* which gives the kinetic energy minus the potential energy of the entire system. The behavior of the system described by the field equations and the equations of motion is always given by an *extremum* (maximum or minimum) of the Lagrangian action.

In physics there are four basic interactions, or forces: electromagnetism, the strong nuclear interaction, the weak nuclear interaction, and gravity.

All of these are represented by fields, and their description, generation, behavior, and associated phenomena are treated and explained by field theories. As just indicated, these fields are generated by sources. For example, an electric field has charge as its source, and a magnetic field has a magnetized object or a current as its source. A gravitational field is generated by anything that has mass-energy. As also mentioned, these fields can be time-varying and they can propagate. Time-varying, propagating fields are often referred to as *waves,* or *radiation.* Thus, we have electromagnetic radiation—light, X-rays, radio-waves—which are really time varying electromagnetic fields. Similarly, a gravity wave or gravitational radiation is a time-varying gravitational field, or the time-varying, propagating changes of curvature through space. Fields also have particles associated with them, both those that function as sources and those that are quanta of their waves (photons for electromagnetic waves and gravitons for gravitational waves). These *bosons* (integer-spin particles) are the force carriers of their respective fields between other particles, or distributions of particles, usually those that constitute matter (half-integer spin particles, like quarks, protons, neutrons, and electrons—the *fermions*).

Finally, at the highest energies, these four fundamental interaction fields probably undergo unification. That is, they become indistinguishable from one another at very high energies. At a relatively low energy, equivalent to a temperature of 10^{15} K (kelvin), the electromagnetic and the weak nuclear interaction become indistinguishable—the electroweak interaction.

Electroweak unification has been securely demonstrated and described; this theoretical achievement is due to Stephen Weinberg and Abdus Salam. At a much higher energy (equivalent to 10^{27} K) the electroweak interaction and strong interaction unify in the Grand Unified Theory (GUT) interaction, and this in turn probably unifies with gravity at an energy equivalent to 10^{32} K, above which is the realm of quantum gravity and quantum cosmology. As of 2002, there was no theory adequately describing these last two levels of unification, nor were there experiments and observations unequivocally requiring them. However, there has been very promising theoretical and experimental progress made on both fronts. If and when total unification of all four fundamental interactions is attained this will complete the unification program that began with James Clerk Maxwell's brilliant unification of the electric and magnetic fields in 1864.

The early history of field theory

The concept of a field first appeared in hydrodynamics in the treatment of continuous media, such as fluids. Many mathematical physicists of the seventeenth and eighteenth centuries treated fluids or continuous bodies by dividing them up into small volumes or elements, but it was John Bernoulli who in 1732 first wrote down the equations of motion for these elements, considering them as point particles. Using this approach, Leonard Euler fashioned hydrodynamics into a field theory by modeling the motion of a fluid by giving its velocity at each point in the fluid, and using partial differential equations of these velocity components as functions of time and of the spatial coordinates. In doing this, the molecular structure of the fluid was neglected and it was treated as a continuum, with key parameters being determined at every point. This enabled researchers to describe the transmission of effects through the fluids. Somewhat later the more challenging problem of the propagation of displacements in solids, where elastic forces are prominently involved, was tackled. This was adequately solved by George Stokes in 1845.

Thus, field theory first emerged to describe the behavior of a continuous medium. There was at that time a different set of important physical phenomena (gravity, and electric and magnetic attraction and repulsion), which seemed to involve action at a distance. In these cases, such as in Isaac Newton's theory of gravity, it was assumed that there was no medium transmitting these interactions and that their effects occurred instantaneously. During the nineteenth century, due to the work of Joseph-Louis Lagrange, Pierre-Simon Laplace, and Siméon-Denis Poisson, the action at a distance in these cases began to be considered somewhat like a field, but without the presence of a fluid or a medium. In the case of gravity, for instance, the force of attraction at any location outside of a massive body can be designated in terms of what a point test mass would experience at each of those coordinate positions. This can be expressed in terms of the gravitational potential V at each position, which satisfies the well-known second-order differential equations of Laplace (empty space) or Poisson (nonempty space). Thus, both the gravitational force and the gravitational potential are fields. As such, they are no longer properties of discernable matter, but of empty space itself.

Despite its representation by a potential field, gravity continued to be considered an action at a distance throughout the nineteenth century because the gravitational potential could not be associated with any discernable medium. The propagation of gravitational effects was not affected by any material changes in the intervening space; it appeared instantaneous, no mechanical model for the action of a medium could be conceived, nor could any energy be located between the gravitationally interacting bodies. It was only in the early twentieth century, with the advent of Albert Einstein's General Relativity (his theory of gravity), that gravitation became recognized as a field theory in the strict physical sense. Electromagnetism, in contrast, began to be considered as a genuine field-theory in the nineteenth century, precisely because it clearly fulfilled these same criteria.

Classical field theory

It was Michael Faraday who in the mid-nineteenth century first showed that action at a distance provides an inadequate description of electric and magnetic phenomena. His studies convinced him that electrical and magnetic influences propagated through a medium and not at a distance. The basic idea is that of a "continuous action" of forces filling space, not of a continuous mechanical action. Faraday's diagrams of lines of force originating in and returning to conductors and magnets stimulated Baron Kelvin (William Thomson) and Maxwell to formulate electromagnetic behavior in terms of fields. In comparing gravitational forces with electromagnetic forces, however, Faraday was unable to extend to gravity his arguments for propagation through a medium. Thus, Newtonian gravity continued to be considered by most, from a physical point of view, to be an "action at a distance" theory.

Faraday's key insights concerning electromagnetism were confirmed by Kelvin, who in the 1840s was able to show that the same mathematical formulae could be used to describe fluid and heat flow, electrical and magnetic behavior, and elastic behavior. Kelvin thus established the important analogies among all five classes of phenomena, as well as that representing electric and magnetic phenomena by lines of force was consistent with their inverse-square falloff. Both Kelvin and Maxwell were careful not to draw conclusions about the reality of physical media from these detailed mathematical analogies. However, once Maxwell had formulated his highly successful electromagnetic field equations, which really provide a detailed quantitative unified description of electrical and magnetic phenomena, he and other physicists began to interpret these fields as a form of matter, so much so that matter in the usual sense gradually came to be looked upon in terms of fields, rather than vice versa. This was especially true once it was clear from Maxwell's theory that propagation of electromagnetic fields is not instantaneous and that electromagnetic energy, which can be transformed into other forms of energy, is contained in the fields themselves. Maxwell also succeeded in associating momentum with the electromagnetic field, and the physicist John Henry Poynting later developed the concept of energy-flux, and showed that this applied in a concrete way to electromagnetic fields and electromagnetic radiation. These developments have all contributed to supporting the conception of electromagnetic fields as a genuine form of matter, and they presaged the discoveries in Special Relativity that mass and energy are equivalent, and later in relativistic quantum theory that all forms of matter are fundamentally interacting fields. Maxwell's theory was the first fully successful and complete field theory, and remains the best example of a classical field theory.

The influence of Special and General Relativity

Along with Maxell's electromagnetic theory, Special and General Relativity strongly reinforced the usefulness and strength of the field-theory perspective, and even the realistic physical interpretations given to fields. The formulation and confirmation of Special Relativity have been especially influential in effecting this. Besides the discovery of mass-energy equivalence, mentioned above, perhaps the most influential event was the 1887 experiment by Albert Michelson and Edward Morley, the most compelling interpretation of which held that "the ether" does not exist and that therefore the velocity of light is constant with respect to any inertial frame (any coordinate system moving at a constant velocity). Thus, there is no absolute standard of rest. Moreover, there is no medium needed for electromagnetic fields to propagate. The fields themselves are fundamental and are, in a sense, their own media. Furthermore, since nothing propagates instantaneously, there are no perfectly rigid bodies or incompressible fluids, as envisioned in Newtonian mechanics. These are idealizations that, strictly speaking, are never realized. What is most impressive is that Maxwell's electromagnetic field theory turns out to be completely consistent with Special Relativity and can be explicitly formulated as such (in Lorentz-invariant fashion) in a natural and straightforward way. This confirms the insights that fields are a basic form of matter and that they are integral and indivisible.

Newton's theory of gravity was not generally looked upon as a field theory in the same way electromagnetism was, but rather as an "action at a distance" theory. Einstein changed that. In formulating his theory of gravitation, he fundamentally conceived space and time as fields that obey field equations, connecting space and time with the mass-energy distribution that they "contain." These space and time fields are the components of the metric tensor that makes space-time measurements possible. They are like, and in fact replace, the gravitational potential of Newton, but they are not defined in a pre-existing background space-time. They *are* the space-time. And this space-time is, in general, not flat but curved, depending on the density and pressure of the mass-energy on the space-time manifold, including all nongravitational (e.g., electromagnetic) fields. As a result, light rays (electromagnetic radiation) and freely moving particles follow the geodesics in curved space-time. Gravity is no longer conceived as a force, strictly speaking, but rather as the curvature of space-time. And light is affected by this curvature, unlike in Newtonian gravitational theory. This is consistent also from the point of view that light possesses energy, which is equivalent to mass, according to Special Relativity. Through observations of the bending and the red-shifting of light rays in gravitational fields, as well as through other observations (including the evidence for the existence of black holes), General Relativity has been impressively confirmed. General Relativity also predicts the existence of gravitational radiation—the propagation, at the speed of light, of variations in the curvature of space-time. This has been indirectly detected. And there is a massive effort to detect these gravity waves directly.

Quantum mechanics and quantum field theory

One of the great accomplishments of twentieth-century physics was the development and experimental confirmation of quantum theory. This began with failures of classical physics to account for the stability of atoms, the photoelectric effect, the explanation of the Planck blackbody spectrum, wave-particle duality, and the intrinsic uncertainties in certain types of measurements. Essentially, it became clear that physical reality, at its most fundamental level, could not be modeled in a continuous way, but only in terms of discrete quanta of energy, angular momentum, spin, and so on. Furthermore, any measurement of a system automatically affects that system in some way, with the Uncertainty Principle always applying. In any quantum measurement, the outcome is never precisely predictable. The theory gives probabilities that any one of a set of possible outcomes will result from a given measurement. All of these issues have been more or less satisfactorily incorporated into quantum mechanics by Erwin Schrödinger, Werner Heisenberg, and others. Paul Dirac properly formulated quantum mechanics within the framework of Special Relativity, yielding relativistic quantum mechanics. As such, in both these formulations, quantum mechanics is not a field theory, but rather a quantum theory of discrete bodies and individual particles in their interactions with one another.

Relativistic quantum mechanics, however, is plagued by a serious problem: it allows for negative-energy states, which would seem to predict an infinite series of decays. It turns out that this problem can be solved only by moving from consideration of single particles to indefinitely many particles. This automatically leads us to consider quantum fields as fundamental, with the particles being localized realizations (modes or quanta) associated with these fields. The result is the development of the extraordinarily successful quantum field theory. The fundamental structure of physical reality has come to be understood in terms of the interaction of these quantum fields, some of which are bosonic, or force-carrying, and some which are fermionic, or particle-constituting.

As mentioned at the beginning, there is strong evidence that at higher and higher energies or temperatures the four fundamental field interactions (electromagnetism, the strong and weak nuclear interactions, and gravity) unify step by step, and become indistinguishable. There are still many unknown details and challenges in constructing a completely adequate unified field theory and in explaining some of the features that physical reality manifests, particularly with respect to the quantum connections between gravity and space-time, as well as gravity and the other three interactions. But quantum field theory as it is understood in the early twenty-first century provides an impressive and reliable, though provisional and incomplete, description and guide to how reality at its most fundamental levels is constituted and behaves.

Relevance to the religion-science dialogue

The principal relevance of field theory to the religion-science dialogue is that it gives a reliable, well tested, and nearly comprehensive account of how reality is put together at its most fundamental levels. It also ultimately sheds light, through its applications in cosmology, on how the universe evolved from an extremely hot, homogeneous, simple, and undifferentiated quantum-dominated state to its present cool, lumpy, complex, and highly differentiated state. This strongly constrains theology in speaking about how creation occurred and about how God acts in creating and in sustaining what has been created. The relationships, processes, interactions, and regularities described by field theory—the laws of nature and physics—must be acknowledged to play a key role as channels of God's creative ordering power in reality. The concept of dynamic interacting fields, along with the auxiliary concepts and phenomena connected with them, can also provide analogies that can be employed in constructive theological programs.

See also FIELD; GRAND UNIFIED THEORY; GRAVITATION; PHYSICS, QUANTUM; RELATIVITY, GENERAL THEORY OF; RELATIVITY, SPECIAL THEORY OF

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WILLIAM R. STOEGER

FITNESS

Fitness is a measure of the relative performance or adaptedness of an organism represented by its genotype in a given environment. The term *fitness* is sometimes also used to describe other biological units, such as the gene or the population. Classically *fitness* is used to describe differences in survival (viability selection as described by Charles Darwin (1809–1882) with the phrase "survival of the fittest"), mating success (sexual selection), and reproductive output (fecundity selection) between individuals characterized by their genotypes and measured as their relative contribution to the next generation in terms of the number of offspring a genotype succeeds in producing and rearing to sexual maturity. A genotype that leaves more offspring will thus have a higher fitness.

In the field of classical population genetics theory, evolutionary changes are exemplified by the change in gene frequency at a single gene locus with two alleles, *A1* and *A2*, in a diploid organism. The modes of selection depend on the fitness of the heterozygote *A1A2* compared to that of the homozygotes *A1A1* and *A2A2*. If one homozygote (e.g., *A1A1*) has the highest fitness, directional selection will favor that genotype and eventually lead to fixation of allele *A1*. A famous example of directional selection is the industrial melanism of the peppered moth (*Biston bitularia*) in England, where the black or melanic morph increased in frequency after the industrial revolution, then decreased in the 1950s when "smokeless zones" were established and tree trunks became lighter, thus giving the black morph a disadvantage due to increased risk of predation by birds.

If the heterozygote has the highest fitness, stabilizing selection or heterozygote advantage will usually maintain both alleles in the population (an example is variation at the beta–globin gene in humans, where heterozygotes have an advantage in regions with malaria, while one type of homozygotes gets sickle cell disease), while heterozygote disadvantage will lead to disruptive selection favoring both homozygotes. This simple theory was developed for one locus in infinite populations and for constant fitness coefficients by, among others, R. A. Fisher (1890–1962) and J. S. B. Haldane (1892–1964) in the 1920s and 1930s. The theory was later modified and expanded to include multiple loci and variable environments, as well as population substructure and finite populations.

The shifting balance theory of Sewall Wright (1889–1988) describes the fitness landscape of more complex multilocus genotypes, where the fitness of certain genotypes has local peak values, while simple changes in genotype will lead to a fitness decrease. Shifts from one peak to another in that landscape require more complex changes with intermittent genotypes of reduced fitness. In small populations random genetic drift may counteract the selective forces that are driven by fitness differences and push populations from one peak to another.

Darwin considered fitness to be a property of the individual; later biologists sometimes use the term to refer to lower levels of organization, such as, for example, a property of the gene (the idea of the selfish gene is based on this unit) or of higher levels, such as, for example, the population. So-called group selection is based on higher units, and the concept of inclusive fitness includes contributions of related individuals who share genes. This concept of fitness has been used to explain the evolution of altruistic behaviors, such as warning calls in birds, which may bring the altruistic individual to higher risk but may benefit its genes by improving the chance of survival of relatives.

See also ADAPTATION; ALTRUISM; EVOLUTION; SELECTION, LEVELS OF; SELFISH GENE; SOCIOBIOLOGY

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FORCES OF NATURE

The term "forces of nature" refers to the capabilities of the natural world that enable its various members to act on and interact with one another. Nature—the whole system of galaxies, stars, planets, and living things, along with the atoms and molecules of which they are composed—is interactive. Each of its parts interacts with its environment—both near and distant—and responds to the various forces acting on it. In current physics, these forces number four: the strong and weak nuclear forces, the electromagnetic force, and the gravitational force. In discussions relating science and religion, there is considerable interest in comparing or contrasting action by the forces of nature with divine action on the natural world.

See also DIVINE ACTION; GRAVITATION; LAWS OF NATURE; PHYSICS, PARTICLE

HOWARD J. VAN TILL

FOUNDATIONALISM

The term *foundationalism* usually refers to theories about the structure of belief formation or belief justification. Beliefs may be formed or justified in one of two ways: non-inferentially (immediately) or inferentially (mediately). The division between "basic" and "nonbasic" beliefs is asymmetrical; nonbasic beliefs are formed or justified by appealing to basic beliefs, which are foundational. For *classical* foundationalists, a basic belief must be self-evident or incorrigible. *Modest* foundationalists argue that meeting other criteria, such as "evident to the senses," may also qualify a belief as basic; further, basic beliefs can be defeasible. Foundationalists in the science-religion dialogue often focus on defending the propriety of basic beliefs and inferences from them.

See also NONFOUNDATIONALISM;
POSTFOUNDATIONALISM

F. LERON SHULTS

FREEDOM

Freedom as understood in the modern West is self-determination by an autonomous being with a rational mind. Precursors to this understanding of freedom begin with Plato in ancient Greece, who shifted the locus of freedom from the political distinction between citizen and slave to the internal will that exercises influence on external events. Aristotle saw in the human will the capacity to harmonize itself with the will of God and the pursuit of the transcendent good and the good life.

Conceptions in Various Religious Traditions

In Hinduism and sister traditions such as Buddhism the doctrine of *karma* places the human person in a causal nexus of moral determinism where past life behavior determines present life status. Liberation (*moksha*) consists of being freed from the wheel of reincarnation, freed for eternity from the effects of karma. A variant of the dispute between grace and merit appears in Hinduism over the role of free human action in salvation. The cat school (*Tenkalai*) argues that God's irresistible grace saves the adept like a mother cat carries her young by the nape of the neck; whereas the monkey school (*Vatakalai*) argues that human free will is required in a way that a baby monkey is required to cling to its mother.

Islam teaches that God (Allah) is in control of the outcome of human acts, whether those acts are free or not. Human beings are free to choose between good and evil; the Qur'an teaches that God will judge mortals on the Last Day according to good and bad deeds. Some Muslims find comfort in predestination as a doctrine that affirms divine control over the course of events. "God leads astray whom he pleases and guides whom he pleases" (Surah 74:34). Human moral responsibility is not obviated by strong reliance upon divine control.

Freedom according to Christian theology belongs preeminently to God, who is absolutely free. God is the one, original, and authentic person through whose creative self-expression all other persons come into existence and are sustained. Human freedom derives from divine freedom, expressed as divine grace. God liberates Hebrew slaves from their Egyptian taskmasters and liberates faithful believers from the threat of sin, death, and the power of the devil. Christian advocates of predestination hold that human salvation is the result of free divine action, a gracious action that bestows eternal life as a gift rather than as a reward required by a legal structure of merit.

Commitment to belief in a single all-powerful God, which Christians share with Jews and Muslims, has led to three theological struggles over the nature of freedom that provide background to the contemporary conversation with science. The first is the predestination controversy. Once it is accepted that human salvation is a gift of divine grace and not the product of human moral achievement, then the question arises: Why do some persons exhibit strong faith in God and others do not? Predestination answers this question by contending that God has eternally decreed that some individuals would be infallibly guided to saving faith and, thereby, to eternal salvation. Those who do not have faith either were not included in the eternal decree; or, according to the double predestination school, they were actually predestined to damnation. The import of predestination is to make salvation solely a product of divine action, not a matter of human freedom. Humans remain free on a daily basis to make routine choices, but their salvation is a matter of divine decree alone.

The second theological struggle focuses on divine power, on God's omnipotence. Once it is accepted that God is all-powerful, metaphysical questions arise regarding the application of omnipotence to causal efficacy. Is God the cause of all things? Of every event? Should we eliminate causal efficacy, contingency, and human action as factors in the created world? If so, is God responsible for evil and suffering? This tempts some to affirm a thoroughgoing predestination, a complete determinism; and to do so not as a corollary to grace but as an implication of omnipotence. The unspoken assumption is that of a fixed pie image of power in the universe: if God gets more power then human beings get less. The fixed pie assumption has led two contemporary theological schools to compromise divine omnipotence. Process theologians in the tradition of Alfred North Whitehead (1861–1947) deny divine omnipotence and proportionately increase the power that local human free decision-making has on the future. Similarly, certain classical theists adopt the Kabbalistic notion of *zimsum,* a primordial self-withdrawal on God's part to permit contingency in nature and freedom in human life. In this case, the self-restriction on God's part is voluntary; whereas for the process theologians it is metaphysically necessary. For both these schools of thought, power is finite and competitive; so to have room for human freedom some proportion of power must be denied to God.

The third struggle in theological conceptuality is to clarify how power begets power, and how freedom begets freedom. Rejected here is the assumption of a fixed pie of power. Rather, theologians influenced by Karl Barth (1886–1968) and liberation theologians posit that God is the absolutely free one and that divine freedom is contagious; when God exerts divine power, it liberates the creation. The creation of the universe from nothing, *creatio ex nihilo,* took an act of divine power; and God's continuing work of creation, *creatio continua,* is similarly an exertion of divine action in the world. Yet this is fully compatible with natural causation, contingency in events, and willful human action. The prayerful cry of petitionary prayer is for God to exert divine power to liberate us from natural disaster, disease, political oppression, or our personal bad habits.

The historical struggles over divine power and human freedom set the stage in Western history for the contemporary debate regarding the relationship of determinism to free will. Rather than see God as the opponent to human freedom, modern Westerners see the causal ubiquity of natural law playing this opposing role. The word 'determinism' refers to lack of contingency in natural events, lack of noncaused events; it is a philosophy deriving from scientific reductionism.

Contemporary definitions of freedom

In the contemporary discussion of freedom versus determinism raised by reductionism among natural scientists, four definitions of freedom are of interest to theologians. First, *political freedom* or liberty is understood as independence from external coercion by government power. Liberation movements pursue freedom to escape economic and cultural coercion as well as political restriction. Philosophies of political liberty usually presuppose belief in natural freedom applied to the individual. Second, *natural freedom* or freedom of the will is the ability of a rational mind to choose between alternatives and make decisions that lead to actions. The locus of natural freedom is the choosing self. This is the Enlightenment view of freedom as self-expression, self-determination, and self-pursuit of happiness. Choosing between good and bad things and acting voluntarily are attributes of an individual's free will. Third, *moral freedom* refers to what the disciples of Aristotle dubbed 'virtue,' the freedom gained when conforming one's life to a higher truth or higher good that transcends the choosing self. For Augustine of Hippo (354–430 C.E.) and Martin Luther (1483–1546) the human self, to be truly free, must be freed from being curved in upon itself; such freedom can come only from a bestowal of God's liberating grace. The Christian variant of moral freedom expresses itself in selfless love of neighbor. Fourth, *future freedom* is the release of human creativity through designing, engineering, organizing, and building in such a way as to influence future events. Freedom here consists of transcending the confines of past precedents and constraints.

Determinism in modern science

Determinism is a philosophical idea that may or may not be attached to a scientific understanding of natural law. The essence of the deterministic view is that natural law is exhaustive and total in its causal application. Once initial conditions are established, every event that follows is bound to happen as it does and in no other possible way. Nothing in nature is contingent; so no room exists for natural freedom or future freedom. Hard determinists hold that no human act of will is free, even if it appears so. Free will is a delusion. Soft determinists hold a version of compatibilism; they believe that human actions are physically caused, but room remains for exercise of free will.

The mechanistic model of the natural world bequeathed to modern science by Newtonian physics presents a closed causal nexus, an exhaustive nexus of events without contingency. If the laws of nature never go on holiday, then what follows is eighteenth-century philosopher David Hume's (1711–1776) repudiation of miracles as events that deviate from unbreakable laws. What also follows is the eclipse of freedom, both divine and human. What appears to be freedom in human experience must be reducible to lawful physical activity, and the appearance of freedom as something supraphysical or spiritual must be a delusion.

In the early twentieth century Newtonian mechanism in physics was replaced by quantum mechanics; determinism was replaced by indeterminism. The activity of the individual electron is contingent, unpredictable; it can be predicted only in statistical quanta. Some contemporary theologians such as Robert John Russell argue that indeterminism at the fundamental physical level is a necessary condition for human free will to appear at the psychological level. Some physicists repudiate indeterminism by posing the theory of many worlds, according to which every potential physical state becomes actual in one or another universe. This would in principle apply to every human state as well, eliminating natural freedom.

Near the end of the twentieth century, Newtonian mechanism reappeared in genetics and neuroscience. Genetic determinism—the widespread belief that human essence is found in DNA and that DNA is determinative of both traits and behavior—has indirect implications for freedom understood as political liberty. The cultural response to the Human Genome Project (initiated in 1990) in conjunction with controversies over gene patenting, cloning, and stem cells lead many to fear an alliance between big science and big money; it is the populist fear that a powerful invisible elite will make decisions regarding human evolutionary future that will release forces beyond the average person's control.

Neuroscience and cognitive theory prompt some philosophers to reduce psychological and cognitive processes to neuronal activity in the human brain. This has led to an alliance between genes and brains that seems to challenge natural freedom with ferocity. If DNA through neural activity turns out to govern behavior, then the genes would turn out to govern human choices. What appears to be a self who makes decisions would be reducible to a complex interaction of genes with environment. Genes might even be found responsible for predispositions to choose between what is moral and what is immoral. Crime and virtue would then be predetermined. No self would need to be transcended by moral freedom, because no self would exist in the first place.

Some opponents of genetic determinism argue for a two-part determinism, genes plus environment. Other opponents defending the Enlightenment doctrine of freedom as self-determination hold to a three-part determinism: genes, environment, and self. In the latter case, the self is an emergent entity not reducible to either genes or environment.

Future freedom is enhanced by the Promethean dimension of genetic determinism, according to which molecular biologists are gaining the knowledge and technology to alter the human germline in such a way as to influence directly the future of human evolution. This future freedom elicits anxiety on the part of many people, because it raises specters of Frankenstein the mad scientist who lets evil loose on society. Those fearing Promethean pride on the part of scientists try to curtail research by saying, "thou shalt not play God." This warning appeals to something allegedly essential or sacred in nature prior to technological intervention; so the commandment against playing God is an attempt to avoid violating nature by legislating against future freedom.

Freedom in theology and science

The commandment against playing God in secular society shares the assumption made by some theologians that there is a fixed pie of power in the universe, that God's power competes with human power. These theologians believe that if God's power is restricted then human power is increased, thereby making human freedom possible. Those who forbid playing God in genetics or other scientific endeavors follow the opposite logic, namely, if human power is restricted then God is freer to act through natural processes.

The advantage for theologians in adopting either the process model or the *zimsum* model is that they can hold to a doctrine of divine creation while allotting to Big Bang cosmology and biological evolution principles such as deep time, contingency, self-organization, and development. The absence of divine power opens an arena within which a dialectic of regularity and chance governs natural occurrences. This is theologically significant because it solves the theodicy problem: suffering and evil on the part of sentient creatures is now the responsibility of self-organization through natural selection. God is exempt from responsibility for what goes wrong. Science and technology fill the hole vacated by God. God's absence makes natural freedom and future freedom possible.

The difficulty faced by theologians who cling to divine omnipotence is that nature's victims, such as the predator's prey or extinct species, must be judged to be part of God's plan. By allowing such waste and suffering, God risks being thought of as cruel. The theological advantage to omnipotence is that God is viewed as the very power by which development is energized and guided, leading the human race through scientific and medical discoveries toward taking control of its own health and wellbeing. God is viewed as the healer, the redeemer. Science and technology become liberating vocations, expanding the horizon of human freedom while imposing increased environmental responsibilities. God's presence makes natural freedom and future freedom possible.

Finally, reductionism raises the question of the status of the human self. Biologist Francis Crick (b. 1916) would eliminate any ontological status to the self or the soul, on the grounds that it is reducible to gene expression and neural firing patterns in our brain. Many who oppose a strict biological determinism substitute a two-part determinism, genes plus environment. In this case 'environment' can refer to the cytoplasm within the cell or to the food our parents place on our plate. Two-part determinism is just as eliminative of the human self or soul as is raw genetic determinism. What most defenders of natural freedom actually advocate is three-part determinism: genes, environment, and self. The self functions as a determinant. The self can be thought of materialistically as an emergent property within evolutionary development; or it can be thought of metaphysically as a divinely imparted soul. It need not have any material substrate other than genes and environment; but its deliberations, decisions, and actions are observable and can be empirically confirmed.

See also DETERMINISM; FREE WILL DEFENSE

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TED PETERS

FREE PROCESS DEFENSE

Process theology's solution to the problem of evil derives from its conception of divine power. God cannot be held culpable for failing to prevent the occurrence of genuine evil because God cannot override, veto, or withdraw the freedom that creatures possess when committing evil. God's power entails the persuasion, never coercion, of free creatures. Conceiving of divine power in this way allows process theists to affirm divine love unequivocally. It also allows them to acknowledge the commonsense notion that some events occur that make the world a worse place than it might have been.

The free process defense originates from the philosophies of Alfred North Whitehead (1861–1947) and Charles Hartshorne (1897–2000). David Ray Griffin (1939–) has further developed and explained this defense. Scientist-theologians such as John Polkinghorne (1930–) and Arthur Peacocke (1924–) have been attracted to the process answer to the problem of evil, and each uses variations of it in his own work. In their view, God has chosen to let the world develop itself in a continual interplay with chance and the necessities embodied in the divinely installed laws of nature, in order for nature to explore its own potentialities. Thus understood, the free process defense is an extension of the free will defense.

See also EVIL AND SUFFERING; FREEDOM; FREE WILL DEFENSE; PROCESS THOUGHT; THEODICY; WHITEHEAD, ALFRED NORTH

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THOMAS JAY OORD

FREE WILL

See DETERMINISM; FREEDOM; FREE WILL DEFENSE

FREE WILL DEFENSE

The occurrence of evil, despite the existence of a perfectly loving and perfectly powerful God, poses a theoretical and existential problem. The Scottish philosopher David Hume (1711–1776) put the problem in the form of questions: "Is [God] willing to prevent evil, but not able? Then he is impotent. Is he able, but not willing? Then he is malevolent. Is he both able and willing? Whence then is evil?"

The free will defense solves the problem of evil by claiming that creatures have power to exert freely some control over their circumstances. Creatures can use freedom for good or evil; evil results from improper creaturely use of freedom. The free will defense solution to the problem of evil provides a basis for claiming that creatures, not God, are culpable for the genuine evil that occurs.

Accidental free will theism. Two general forms of the free will defense exist: *accidental free will theism* and *essential free will theism.* Accidental free will theism purports that although God essentially possesses all power as omnipotent, God voluntarily gives up power and becomes self-limited so that creatures might act freely. While creatures possess power for freedom on loan from God, this omnipotent God retains the capacity to veto (i.e., withdraw or override) this divinely given power. Accidental free will theists claim that God voluntary became self-limited at the creation of the universe as God bestowed the universe with the birthright of freedom. God grants freedom voluntarily in each present moment as the direct and constant source of power for all creatures. While God always uses divine power lovingly, creatures sometimes use God-derived power in evil ways.

Many forms of accidental free will theism have been proposed. Alvin Plantinga (1932–) advocates one form, in which he argues that although it is possible for an omnipotent God to create a world in which creatures are not free, a loving God would not create such a world. Instead, a loving God would create a world in which creatures have the opportunity to make genuinely free decisions among various morally conditioned options. Such a world is the best of all possible worlds that God could have created.

John Polkinghorne (1930–) and Arthur Peacocke (1924–) also advocate a form of accidental free will theism. The form they embrace, correlated to the Greek word *kenosis,* entails that God is self-emptied of some power in order for creatures to possess power for freedom. This self-limitation occurs because God lovingly desires others with which to relate and create. Some forms of accidental free will theism suppose that God's loving nature drives the divine desire for others to express freedom, even when the expression of creaturely freedom occasionally results in pain and suffering.

Critics of accidental free will theism argue that if God is omnipotent in every possible world, the best possible world that God would create would be one in which people invariably choose rightly. Other critics acknowledge that it may be logically possible that a perfectly loving and all-powerful God exists despite the occurrence of genuine evil, but the amount of evil makes the existence of such a God evidentially implausible. Perhaps the most severe criticism of accidental free will theism is that it does not explain why God does not prevent genuine evils. A God who is voluntarily self-limited ought to become un-self-limited occasionally, in the name of love, to veto the freedom expressed by perpetrators of genuine evil.

Essential free will theism. Essential free will theism, also known as the *free process defense,* views divine omnipotence as meaning that God is the most powerful being in existence, rather than possessing all power in the universe. This form of the free will defense speculates that all individuals necessarily posses some power that cannot be completely overridden, withdrawn, or vetoed by anyone, including God. Advocates of this position claim that culpability for genuine evil rests upon the shoulders of creatures that use their own power wrongly.

Process theist David Ray Griffin (1939–) posits a form of essential free will theism that entails that God is metaphysically unable to determine creaturely decisions unilaterally. Creatures possess self-determinative power that cannot be withdrawn or overridden by God, and the fact that individuals possess power for freedom is an eternal metaphysical law. God cannot circumvent these metaphysical laws of freedom, partly because God did not create them. God is not indictable for failing to prevent genuinely evil events from occurring because these metaphysical laws prevent God from removing power and freedom away from creatures who misuse freedom. Griffin's free will defense solves the problem of evil by denying that God is able to prevent genuinely evil occurrences resulting from free creaturely decisions.

The recurring criticism of Griffin's hypothesis ultimately derives from the claim that God did not create the metaphysical laws that govern actual existence. Most theists have assumed that part of what it means for God to be the creator is that God created the metaphysical laws that govern what it means for all things to exist. Griffin's process free will defense also envisions God as always relating to and creating from some realm of nondivine entities. This hypothesis undermines the classic Church doctrine of God's capacity voluntarily to create the world out of absolute nothingness (*creatio ex nihilo*).

Dialogue with science. Both the accidental and essential forms of the free will defense posit a theodicy that reinterprets the concept of divine omnipotence in light of creaturely freedom. Culpability of genuine evils is removed from a perfectly loving God and is placed upon creatures that have the ability to exert freely a degree of control over their circumstances. This reinterpretation of divine power and creaturely responsibility is profoundly important for the science and religion dialogue, partly because many atheists have chosen not to believe in the existence of God due to the problem of evil. If convinced by the free will defense that God can be considered perfectly loving despite the occurrence of evil, a platform may be secured for discussing other dialogue issues.

See also EVIL AND SUFFERING; FREEDOM; FREE PROCESS DEFENSE; KENOSIS; THEODICY

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FREUD, SIGMUND

Sigmund Freud, well known as the founder of psychoanalysis, was born in 1856 in Freiberg, Moravia. He moved with his family to Vienna, Austria, at the age of four. Freud received a thorough scientific training in his early years and went on to a distinguished career in scientific research, establishing himself as a leading neuropathologist. He made important contributions to the study of the *neuron* (nerve cell) and wrote influential treatises on aphasia and cerebral palsy. In his later career, Freud labored to establish psychoanalysis as a form of natural science. As a late representative of Enlightenment thinking, Freud joined the issue of the relation between science and religion most directly in his long drawn out debate with Oskar Pfister (1873–1956), a Swiss Lutheran pastor and his devoted friend of many years.

Debate with Pfister

The debate came to a head in Freud's writing of *The Future of an Illusion* (1927). Pfister took up the challenge and responded in a lengthy article, "The Illusion of the Future" (1928). The interchange was, in fact, the high point of a dialogue contained in letters exchanged over more than thirty years. The two men differed radically in their assessment of and attitudes toward religious experience and belief. Freud viewed religious beliefs as forms of illusion (if not delusion) and religious experience and practice as universal forms of obsessional neurosis. Freud continually presented himself to Pfister as an unbeliever, a "godless Jew" (1928, p. 170).

The analytic insistence on the resolution of transference, rather than the dependence (as he saw it) of religion on transference in the sense of emptional attachment and dependence, was central in Freud's assessment of religion. In 1928, Freud wrote to Pfister:

> The rift, not in analytic, but in scientific thinking which one comes on when the subject of God and Christ is touched on I accept as one of the logically untenable but psychologically only too intelligible irrationalities of life. . . . In contrast to utterances as psychologically profound as "Thy sins are forgiven thee; arise and walk," . . . if the sick man had asked: "How knowest thou that my sins are forgiven?" the answer could only have been: "I, the Son of God, forgive thee." In other words, a call for unlimited transference. And now, just suppose I said to a patient: "I, Professor Sigmund Freud, forgive thee thy sins." What a fool I should make of myself. To the former case, the principle applies that analysis is not satisfied with success produced by suggestion, but investigates the origin of and justification for the transference. (Meng and Freud, pp. 125–126)

Yet, Freud clearly envied the power of religion: "As for the possibility of sublimation to religion, therapeutically I can only envy you. But the beauty of religion certainly does not belong to psychoanalysis. It is natural that at this point in therapy our ways should part, and so it can remain" (Meng and Freud, p. 63).

Freud's argument in *The Future of an Illusion* was fairly straightforward. In opposition to nature, civilization exacts a heavy price in the form of instinctual renunciation. In addition to prohibitions and privations, imposed externally or internally by the superego, culture proposes certain ideals as its highest achievements. The satisfaction associated with such ideals is basically narcissistic. In this unending struggle between civilization and the forces of nature, religion serves to defend civilization against nature. Thus, "Man's self-regard, seriously menaced, calls for consolation; life and the universe must be robbed of their terrors; moreover his curiosity, moved, it is true, by the strongest practical interest, demands an answer" (1927, p. 16). In their hopelessness, mankind turn the forces of nature into gods with whom they can associate on relatively human terms. But this transformation follows the prototype of the original infantile state of helplessness in relation to one's parents. The gods thus are transformed fathers, who could be both feared and looked to as sources of protection against unknown dangers.

Religious ideas, therefore, are in essence illusions. They are enunciated as dogmatic teachings rather than as the product of experience or of argument and proof. As Freud proclaimed: "They are illusions, fulfillments of the oldest, strongest, and most urgent wishes of mankind. The secret of their strength lies in the strength of those wishes. As we already know, the terrifying impression of helplessness in childhood aroused the need for protection—for protection through love—which was provided by the father; and the recognition that this helplessness lasts throughout life made it necessary to cling to the existence of a father, but this time a more powerful one" (1927, p. 30). Religion, like obsessional neurosis in childhood, becomes a universal obsessional neurosis of humanity, arising out of the Oedipus complex, specifically out of the relationship to the father.

Science and religion

Freud's polemic against religion was cast in the form of a radical opposition between natural science and religion. Religion had failed in making the majority of people happy or, for that matter, in bringing them to a more moral condition of life. Rather it achieved little more than keeping them submissive to religious beliefs and practices. Freud attributed the decline of religion to the rise of natural science. He observed:

> We have heard the admission that religion no longer has the same influence on people that it used to. . . . And this is not because its promises have grown less, but because people find them less credible. Let us admit that the reason—though perhaps not the only reason—for this change is the increase of the scientific spirit in the higher strata of human society. Criticism has whittled away the evidential value of religious documents, natural science has shown up the errors in them, and comparative research has been struck by the fatal resemblance between the religious ideas which we revere and the mental products of primitive peoples and times. (1927, p. 38)

Anticipating the grim vision later enunciated in *Civilization and Its Discontents* (1930), Freud painted a dire picture of the weakening of the influence of religion on the mass of people. He argued that incestuous and murderous passions would surge to the surface without the suppressive force of religious convictions—"If the sole reason why you must not kill your neighbor is because God has forbidden it and will severely punish you for it in this or the next life—then, when you learn that there is no God and that you need not fear His punishment, you will certainly kill your neighbor without hesitation, and you can only be prevented from doing so by mundane force" (1927, p. 39).

Freud's answer, of course, is to replace religion with science. Since religion has proven so deceitful, misguided, untrustworthy, and oppressive, humankind is obviously better off without it. Moreover, people can do without illusions, and the sooner they abandon their dependence on such infantile illusions, the better off they will be. Moreover, those who abandon such illusions are not without resources or assistance. Their scientific knowledge, which is increasing every day, gives them power to deal with and control their environment, to face the demands of harsh reality more effectively. And, Freud says, "as for the great necessities of Fate, against which there is no help, they will learn to endure them with resignation." (1927, p. 50)

Freud's reply to this imagined argument seems to lack conviction. Certainly, he says, no one has to tell him about the difficulty of avoiding illusions, and perhaps his own hopes, rooted in scientific methodology, are illusory too. But at least his illusions are not, like religious ones, incapable of correction. To that extent, they are not delusions, as religious convictions would be. Finally, he holds out some optimism that people can overcome and free themselves from their neurotic entanglements in virtue of better scientific knowledge, specifically psychoanalysis.

Freud stakes his modest claim for the superiority of the human intellect to religious beliefs:

> We may insist as often as we like that man's intellect is powerless in comparison with his instinctual life, and we may be right in this. Nevertheless, there is something peculiar about this weakness. The voice of the intellect is a soft one, but it does not rest until it has gained a hearing. Finally, after a countless succession of rebuffs, it succeeds. . . . It will presumably set itself the same aims as those whose realization you expect from your God (of course within human limits—so far as external reality, "Ananke," allows it), namely the love of man and the decrease of suffering. (1927, p. 53)

In "The Illusion of the Future," Pfister summarized the Freudian viewpoint in one trenchant sentence: "The God, Logos, hurls the God of religion from the throne and reigns in the realm of necessity, about whose meaning we, in the meantime, do not know the least." (p. 172)

See also PSYCHOLOGY; PSYCHOLOGY OF RELIGION

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FUNCTIONALISM

Functionalism is a schema of explanation: All parts of a system fulfil a necessary, latent function for the system as a whole, its stable equilibrium (principle of homeostasis), or its survival. Functionalism, thus, is a descendant of earlier teleological or finalistic conceptions. It can be applied to nearly all complex systems, but functional explanations are not a unitary phenomenon across disciplines.

Functionalism in sociology

Stimulated by Auguste Comte (1798–1857), Herbert Spencer (1820–1903), and especially Emile Durkheim (1858–1917), and encouraged through the anthropologists Bronislaw Malinowski (1884–1942) and A. R. Radcliffe-Brown (1881–1955), functionalism became important in sociology. Specific structural-functional macro-theories, such as that proposed by Talcott Parsons, describe religious institutions, norms, and symbols with respect to their output on integration, legitimization, compensation, and socialization for the society as a whole, its equilibrium, or its survival. The function of religion is destined for its power of integration (e.g., Durkheim), its role to institutionalize cultural-social norms (Parsons), or its ability to cope with experiences of contingency and reducing complexity (Nikklas Luhman).

This functional conception of religion has been criticized with respect to the epistemological and cognitive status of religious notions, regardless of the contribution of religion to the survival of human cultures. In addition, though the notion of stable equilibrium in functional analysis enables one to define what is dysfunctional and allows the search for functional equivalents, it needs to be defined in its temporal context and can hardly cover social change; in other words, it was accused of being conservative. However, functionalists can easily dismiss this criticism: Contributing to an optimum is adaptive, not legitimate. Some functional theories do not even have a static or equilibrium bias (Luhmann). Modern (neo)functionalism (which takes cybernetic concepts into account), theories about the evolution of religion proposed by Robert Bellah (which mediate the structural-functional model and historic-genetic model of social evolution), and autopoietic systems theories like that of Luhmann all try to avoid this and other criticism mentioned below.

Functionalism in biology

The form of a functional explanation in biology is the same as in sociology: It explains the presence of a trait as solution to a hypothetical design problem to assure that the needs of the individual or group are satisfied. Functional explanations for the needs of the genes are especially popular in sociobiology. Intentions are not involved.

Controversies in sociology and biology roughly concern (1) evidence, (2) explanation, and (3) the selection question. First, opponents like Richard Lewontin argue that stories are being told in sociobiology that have little statistical evidence, are incomplete, and are not empirically testable. Functionalism is accused of "adaptive failure": Adaptiveness does not assure presence of a trait, and it does not give criteria for normality and empirical measures for survival. In the same vein, functionalism is accused of eliminating the truth-question: The issue is not whether the propositions are true or whether there is evidence for believing them to be true, but how holding beliefs is functional. Second, the issue of different levels of explanation is controversial: Is the gene level sufficient for sociobiological explanations? Or do also the individual or the group level have to be considered? Also, the relation of functional explanations to mere functional descriptions and to chemical, causal explanations is controversial. Third, functional explanations in biology do better than those in sociology, it is argued, because they offer an answer to the selection question, natural selection, whereas mechanisms for cultural selection have not been satisfactorily developed. Nevertheless, as Wolfgang Stegmüller posits, functional analysis can be logically correct, empirically substantial, and highly valuable as a heuristic research program. Despite these controversies, (neo)functionalism dominated mainstream sociological and anthropological theories for most of the twentieth century. Functionalist approaches are also prominent in biology.

Functionalism in philosophy of mind

In contemporary philosophy of mind, functionalism is one of the most important theories. Developed in the 1960s by Hilary Putnam and Jerry Fodor, a wide range of different versions has been developed since. The basic thesis is: Mental states are functional states caused by external sensory inputs, causing external behavioral outputs, and causally related to other functional states. One function may be realized in different ways in different cases (multiple realizability). One can roughly distinguish between *common-sense or analytic functionalism,* which deals with meanings of mental vocabulary; *scientific, empirical, or psycho-functionalism,* in which neurobiology lays down the characteristics of functional roles of mental states; and *machine- or computer-functionalism,* where the relation of mind to brain is thought to be equivalent to the relation of software to hardware, usually excluding intentionality and teleology. This computer functionalism, supported by fruitful research on artificial intelligence, has been investigated by Putnam, as well as others, as a worthwhile reaction to a materialistic or physicalistic view of mind because it does not attribute mental states only to humans or living organisms with a similar central nervous system. Like functionalism in general, it hardly gives sufficient justice to qualitative phenomena.

Functionalism in science and religion

Functional approaches are also highly relevant to the science and religion dialogue, mainly in interpretations of ideas about nature and God. An approach that historians of science and religion like John H. Brooke have found useful is to ask what function theology plays within the sciences and vice versa. Religious belief can function as a presupposition of, or sanction for, science. Religious belief could even provide a motivation for science if one happened to believe that the more one uncovered of the intricacies of nature the greater the evidence of divine intelligence. Robert John Russell has even suggested that scientific research programs such as Big Bang Theory and Steady State

Theory have been motivated by religious respectively atheistic worldviews. Religion may also have reinforced aesthetic criteria, such as ideas of simplicity, elegance, and harmony in theory selection. The aim of a functional analysis is to uncover the uses to which natural theology was put, even in the fields of politics.

Ralph Wendell Burhoe's scientific theology is a functional approach to religion. Based upon writings of the sociologist Donald T. Campbell, Burhoe argues for a positively selected role for religion in the survival of cultures: Only religions can enable the shift from selfishness to altruistic behavior. He even argues for a continuing role for religion or a functional equivalent in the development and survival of human culture, proposing his scientific theology, which incorporates the scientific worldview. Critical reactions to this approach show that a functional approach to religion within a scientific framework has to be complemented by a functional approach to science within a religious or theological framework. This has been done by Philip Hefner from the point of view of a distinct theological anthropology. The integration of both concepts could have an even more liberating effect on the science and religion dialogue.

See also ARTIFICIAL INTELLIGENCE; MIND-BODY THEORIES; MIND-BRAIN INTERACTION; NEUROSCIENCES; TELEOLOGY

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FUNDAMENTALISM

Two sets of complex ways by which contemporary people look at reality coexist and often clash. The code word most frequently used for one set of views is *fundamentalism.* The other is referred to as *science,* as in "the scientific worldview." Science has developed over many centuries and has taken different forms since at least ancient Egypt, Greece, and Rome. At its heart are notions such as these: Scientists must be able to observe cause and effect, and they must be able to replicate experiments to test their validity. Such notions have to do with methods and serve mainly practical purposes.

It happens, however, that many scientists and science theorists become so engrossed in the method and its many positive results that they see it as an all-purpose explanation of the world. Anything that cannot be subjected to the cause-and-effect approach is suspect. Almost inevitably, habits of attention to science become preoccupying. More than a few devotees of the scientific worldview come to regard it as exclusive. Any alternatives that challenge it have to be refuted or repudiated.

The term *fundamentalism* was first applied to Protestants in the United States in the 1920s, but it now represents a set of phenomena that can be observed in most cultures where religion has influence and especially in cultures where religion dominates. Fundamentalism is almost always associated with religion, but some scholars also see it as an outlook on life that can characterize the nonreligious as well. In fact, some theological scholars claim that those who are devoted without question to the scientific worldview sometimes approach it as uncritically as most scientists see religious fundamentalists defending their worldviews.

If the word *fundamentalism* was coined in the twentieth century, it must have been needed to describe a new reality. By common consent, the word points to phenomena different from what is suggested by the related words *conservatism, traditionalism,* or *orthodoxy.* The difference lies chiefly in the fact that fundamentalism is reactive. Its defenders "fight back" against what they feel might undercut or assault what they believe. Such fundamentalism is especially present in the "religions of the book": Christianity, Islam, and, to a lesser extent, Judaism. Fundamentalism is present in other forms in Buddhism and Hinduism, but the lines between religion and science are drawn differently in these traditions.

Religions of the book also speak of cause and effect. In their case, the cause is philosophy's "First Cause," which translates into "God." The means of producing effect is the revelation of God through prophets, events, and a sacred book. It is difficult for devotees of the book to subject it to experiment. How does one "replicate" the creation of the world or the presence of prophets who profess to speak about realities that are not testable in the laboratory? How does one "repeat" events that belong to faith, such as the resurrection of a God-Man or a journey into the heavens by a prophet Muhammad on his horse?

Ordinarily people can live with the two worldviews, which do not always have to be seen as competing. Religion can address some aspects of life and science can address others. But fundamentalists have great difficulty picturing how the two worldviews can coexist in the same mind and the same culture. To fundamentalists, one worldview must be right and the other wrong. One is of God and the other is anti-God, perhaps of Satan.

Fundamentalists react or fight back against threats to their communities, traditions, and ways of life. Usually the term for what they attack is *modernization* and all that goes with it. Fundamentalism took shape in countering the assaults of what modernity brings. Not to fight back is to play into the hands of God's enemy and to see the possible destruction of all that one believes.

Technology provides the most profound impact of modernization among citizens around the globe and in all the religions. Technology might include mass communication, rapid means of travel, highly developed weaponry, and the like. With it may come social arrangements that disrupt community. In the modern world, guided by technology, people migrate and spread alien ideas in traditional cultures. While many adapt, fundamentalists say their adherents dare not.

Paradoxically, however, most fundamentalists are very comfortable with technology. Jewish fundamentalists in Gush Emunim in Israel have highly proficient weapons and systems of communication. The modern revolutionary Islamic movements, from that of the Ayatollah Khomeini in Iran in the 1970s to the al-Qaeda terrorists in Wahhabi Islam at the beginning of the twenty-first century, have exploited technologies from tape recordings to the Internet. In the United States, Christian fundamentalist broadcasters are much more effective in the use of technical media than are their nonfundamentalist competitors.

What has happened? Is there, in fact, compatibility between two worldviews that were opposed root and branch? As one studies Islamic and Christian fundamentalisms, it becomes clear that the leaders are able to separate the practical instruments of technology from the scientific theories and experiments that made them possible.

This does not mean that all fundamentalists oppose all science. Many are, in fact, experts in hard sciences. The largely fundamentalist American movement called *creation science* includes people with Doctor of Philosophy degrees, often in the hard sciences where "facts" are determinative. They might accept but one miracle: That their book is the utterance of God. From there on, they will draw "facts" from the sacred book and approach those facts the way they would approach species in biology.

Islamic and other non-Western fundamentalists aim their reactionary efforts against the West, which is the source of so much science and the philosophy of science. The West is seen as the intrusive agent that has exported science and made the non-West dependent upon its hated alternative. And the science that comes from the West tends to arrive with trappings, which may include scientists and technicians who ignore or have disdain for religion. In a world that is gradually being dominated by technology, whether in medicine, opinion formation, or weaponry, the fundamentalist rejection of science is seen as dangerous among moderate coreligionists or people of secular mentality.

Cultures dominated by fundamentalism may eventually be able to overcome suspicion and retrieve from their heritage the variety of approaches that helped them lead in science, as was the case with medieval Islam. Until then, it will remain necessary for regimes dominated by fundamentalists to borrow some coveted features of scientific development, such as modern medicine. Whether such regimes can remain players on the global scene and serve their constituents without developing their own scientific research traditions is a fateful question both for fundamentalist-ruled nations and those who experience the dangerous expressions of their reaction.

See also CHRISTIANITY, EVANGELICAL, ISSUES IN SCIENCE AND RELIGION; CREATIONISM; CREATION SCIENCE

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GAIA HYPOTHESIS

Gaia is the name of the Greek goddess of the Earth. The Gaia hypothesis is that the Earth is more worthy of the respect and reverence once shown to Gaia than modern people have supposed. According to this hypothesis, the Earth is a self-regulating system, of which humans are an unruly part. In particular, the organisms on the Earth's surface play a major role in determining the composition of the atmosphere to ensure that it is favorable to life. Some proponents judge from the scientific evidence that the Earth has its own intelligence and depict it in almost personal, quasi-divine, terms. This provides religious support for concern about particular features of the global ecosystem.

See also Animal Rights; Biological Diversity; Deep Ecology; Ecofeminism; Ecology; Ecology, Ethics of; Ecology, Religious and Philosophical Aspects; Ecology, Science of; Ecotheology; Sacramental Universe

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GALILEO GALILEI

The condemantion of Galileo by the Roman Catholic Church in 1633 is one of the most dramatic incidents in the long history of the relations between science and religion. Galileo claimed in his *Dialogue on the Two Chief World Systems,* published the year before, that the sun-centered system of Copernicus was not only a convenient mathematical device for calculating the position of the planets but that it was the physical truth. This appeared to many Christians to run counter to statements in the Bible where the sun is described as mobile and the earth as stationary.

The clash between scientific truth and biblical revelation could have been avoided if Galileo, who had no decisive proof that the earth moves, had been more cautious and if theologians, who tended to be dogmatic, had not assumed that the Bible was to be interpreted literally whenever it mentioned natural events.

Early life

Galileo Galilei was an Italian astronomer, physicist, and natural philosopher. He was born in Pisa on February 15, 1564, and died in Arcetri on January 8, 1642. Galileo studied at the University of Pisa where he became Professor of Mathematics in 1589. Three years later he moved to the University of Padua where he taught elementary astronomy, mathematics, and physics. Medical students made up the majority of his audience, and he also lectured on fortification and military engineering to young noblemen.

Copernicanism

The first indication of Galileo's commitment to the Polish astronomer Nicolaus Copernicus (1473–1543) appeared in a letter that Galileo wrote to his former colleague at Pisa, Jacopo Mazzoni, in 1597. In August of that year he received a copy of Johannes Kepler's *Mysterium Cosmographicum,* in which the heliocentric theory of the solar system was vindicated on mathematical and symbolic grounds. After reading the preface, Galileo wrote to Kepler (1571–1630) to voice his approval of the view that the earth is in motion, but also to express his fear of making his position known to the public at large.

Around 1602, Galileo began making experiments with falling bodies in conjunction with his study of the motion of pendulums. He first expressed the law of freely falling bodies, namely the fact that speed increases as the time squared, in 1604, but claimed to have derived it from the assumption that speed is proportional to distance (whereas, as he later realised, speed is proportional to the square root of the distance). In the autumn of 1604, the appearance of a supernova gave him the opportunity to argue that heavenly matter is not unchangeable.

In July 1609, after hearing that a Dutchman had invented a device to make distant objects appear nearer, Galileo built one himself and gave a demonstration of his telescope from the top of the Campanile of San Marco in Venice. The practical value for sighting ships at a distance impressed the Venetian authorities who confirmed Galileo's appointment for life and raised his salary from 520 to 1,000 florins, an unprecedented sum for a professor of mathematics. Galileo never quite mastered the optics of his combination of a plano-convex objective and a plano-concave eyepiece (an opera glass), but he succeeded in producing a twenty-power telescope, which he turned to the sky in 1610. What he saw is reported in the *Sidereus Nuncius* (The Starry messenger), which appeared in March 1610. The work was to revolutionize astronomy. The moon was revealed as covered with mountains, new stars appeared as out of nowhere, the Milky Way dissolved into a multitude of starlets and, more spectacular still, four satellites were found orbiting around Jupiter. This was particularly important since, if Jupiter was revolving around a central body with four attendant planets, it could no longer be objected that the earth could not carry the moon around the sun. Jupiter's satellites were not a decisive argument for Copernicanism, but they removed a major obstacle to having it seriously entertained by astronomers.

The Grand Duke of Tuscany, Ferdinand, died in January 1609 and was succeeded by his son, Cosimo II. Galileo had wanted to return to Florence for some time and he realised that his newly-won fame might assist him in effecting a change of residence. He christened the satellites of Jupiter Medicean stars in honour of Cosimo and, in July 1610, he was appointed Mathematician and Philosopher of the Grand Duke of Tuscany. Soon thereafter he discovered that Venus has phases like the moon, and that sunspots move across the surface of the sun.

Theological objections

In December 1613, theological objections were raised at a dinner at the court of the Grand Duke in Pisa. Galileo was absent but his disciple Benedetto Castelli defended his views when questioned by Christina of Lorraine, the Grand Duchess of Tuscany and the mother of the Grand Duke. Galileo felt that the matter was important enough to write a long letter to Castelli, dated December 21, 1613, in which he argued that the heliocentric system was not at variance with the Christian faith. On the fourth Sunday of Advent 1614, a Dominican friar, Tommaso Caccini, inveighed against the Copernican system from the pulpit of the church of Santa Maria Novella in Florence. Another Dominican, Nicolo Lorini, denounced Galileo to the Inquisition. Galileo then wrote a long letter to Christina of Lorraine, where he developed the view that God speaks through the book of nature as well as through the book of Scripture, and that the Bible teaches people how to go to heaven, not how the heavens go. In 1615, Cardinal Robert Bellarmine wrote a letter stating that in the absence of a conclusive proof for the motion of the earth, Galileo and astronomers should content themselves with speaking hypothetically. The Cardinal added that should such a proof become available then the passages in the Bible that seem to say that the earth is at rest would have to be reinterpreted. In 1616, Copernicus's *On the Revolutions of the Heavenly Spheres* was placed on the list of proscribed books and Galileo was privately, but nonetheless officially, warned not to teach orally or in writing that the earth revolves around the sun.

The debate on the comets and Galileo's trial

In 1618 great excitement was generated over the appearance, in rapid succession, of three comets. Galileo thought that they were merely optical phenomena caused by refraction in the atmosphere and he wrote a *Discourse on the Comets* to criticise the account of Father Orazio Grassi (1583–1654), a professor of mathematics at the Collegio Romano, who claimed the comets were real bodies beyond the moon. Grassi published a rejoinder, to which Galileo replied. The result was bitter enmity between himself and the Jesuits.

What changed Galileo's Copernican fortune was the election of Cardinal Maffeo Barberini to the Roman Pontificate in 1623. The following spring Galileo journeyed to Rome, and the new Pope, Urban VIII (1623–1644), granted him no less than six audiences. Galileo returned to Florence feeling that he could now write about the motion of the earth. In January 1630 his long awaited *Dialogue on the Two Chief World Systems* was ready for publication and the manuscript was sent to Rome where a friend, Giovanni Ciampoli, played a vital role in securing permission to print the book. Ciampoli exceeded his powers and was largely responsible for Galileo's subsequent trouble.

The *Dialogue* had gone to press in Florence in June 1631. The publisher had decided to print a thousand copies, a large edition for the time, and the work was not completed until February 1632. Copies did not reach Rome until the end of March or early April. Pope Urban VIII created a commission to investigate the licensing of the *Dialogue*. In the file on Galileo at the Holy Office the commission found an unsigned memorandum of 1616 stating that he had been enjoined not to teach that the earth moves. The commission concluded that Galileo had disobeyed a formal order of the Holy Office, and Galileo was summoned to Rome, arriving, after much delay, on February 13, 1633. Despite his vigorous denial, Galileo was judged to have contravened the orders of the Church. On the morning of June 22, 1633, he was taken to a hall in the convent of Santa Maria Sopra Minerva in Rome and was made to kneel while the sentence condemning him to imprisonment was read out aloud. Still kneeling, Galileo formally adjured his error. He was allowed to leave for Siena and later, in 1634, to return to Florence, where he was confined to his house in Arcetri.

Later years and modern assessment

Galileo sought comfort in work, and within two years he completed the *Discourse on Two New Sciences,* the book on which his lasting fame as a scientist rests. In this work Galileo studied the structure of matter and the strength of materials, and explained motion in the light of the times-squared law of falling bodies and the independent composition of velocities. Together these laws enabled him to give an accurate description of the parabolic path of projectiles. When he cast about for a publisher, he came up against a new problem: the Church had issued a general prohibition against printing or reprinting any of his books. Galileo's manuscript was sent to the Protestant Louis Elzevier in Holland, where it appeared in 1638. Galileo became blind in that year, and he remained under house arrest until his death on January 8, 1642, five weeks before his seventy-eighth birthday.

In contemporary times, the Roman Catholic Church has recognized that the trial of Galileo rested on a misunderstanding of the moral authority of the Church. This was clearly expressed by Pope John Paul II in 1983 at a commemoration of the 350th anniversary of the publication of the *Dialogue on the Two Chief World Systems*. The Pope declared that divine revelation does not involve any particular scientific theory of the universe, and that the Holy Spirit does not guarantee our human explanations of the physical constitution of reality. Galileo had made exactly that point in his letter to Christina of Lorraine.

See also ASTRONOMY; CHRISTIANITY, ROMAN CATHOLIC, ISSUES IN SCIENCE AND RELIGION; COSMOLOGY; GRAVITATION; MATHEMATICS; SCIENCE AND RELIGION, MODELS AND RELATIONS

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WILLIAM R. SHEA

GAY GENE

See HUMAN GENOME PROJECT

GENE-CULTURE COEVOLUTION

See BEHAVIORAL GENETICS; CREATION; DESIGN; EVOLUTION, BIOCULTURAL; EVOLUTION, HUMAN; GENETIC DETERMINISM; GENETICS; NATURE VERSUS NURTURE; SOCIOBIOLOGY

GENE PATENTING

Patents give the patent-holder the right to exclude others from making, using, or selling an invention for a limited period of time (generally fifteen to twenty years). They do not confer on patent holders the right to do anything they wish with the invention. Countries regulate patents differently: Many grant patents to the *first to file,* while the United States grants patents to the *first to invent.* Patent rights are extended internationally through trade negotiations and political treaties. In the biotechnology arena, patents protect large financial interests.

Patent law in the United States

U.S. patent law requires that the invention (process or product) be: (1) novel—not already in the public domain; (2) non-obvious—not an obvious extension of prior art; (3) useful; and (4) fully disclosed. Interpretations of each criterion are contested.

Prior to 1930, products of nature could not be patented in the United States. The Plant Patent Act of 1930 permitted plant breeders to patent new plants. Until 1980, however, nonplant living matter was not patentable. Two legal cases changed the picture. By determining that a strain of bacteria constituted a patentable invention *(Diamond v. Chakrabarty),* the U.S. Supreme Court set the stage for patenting organisms as human inventions. (However, at least one critic, Mark Sagoff, argues that Chakrabarty's work did not involve a unique process and should not have been considered a human invention.) Within a few years, the Patent and Trademark Office was granting patents on bioengineered mice and other living organisms.

The second crucial case was *Moore v. Regents* in 1990. Tissue excised from John Moore during medical treatment was used to develop a commercially valuable line of cells on which a patent was granted to the researcher. Moore sued. The California Supreme Court determined that Moore did not have a proprietary right to his excised tissue or to the cell line developed from it. This decision opened the door for additional efforts to derive patentable tissues from "excess" body parts.

Once patents were granted for living organisms and tissues derived from body parts, it was not long before the Patent and Trademark Office began to permit patents on genes and DNA fragments. Efforts to map and sequence the human genome then sparked a "gold rush" on patents for human genes. By the end of 2000, Human Genome Sciences, Inc., a pharmaceutical company, was reported to hold over one hundred patents on human genes, with applications pending for more than 7,500 additional patents.

Objections to gene patenting

The patenting of genes, organisms, and tissues derived from the human body has not gone undisputed. In 1995, representatives of some eighty religious organizations signed a *Joint Appeal Against Human and Animal Patenting.* For many religious representatives, permitting patents on life forms is arrogating to humans what rightly belongs only to God: "We believe that humans and animals are creations of God, not [of] humans, and as such should not be patented as human inventions."

Indeed, for some, the very framing of the issue as a question of patenting is problematic, since the language of patent rights already determines what questions can be raised. Those who believe that God alone is the author and inventor of living beings would prefer to speak in terms of God's dominion and human duties of stewardship rather than in the language of human rights and patents to human "inventions." Thus, public discourse may already privilege some perspectives and disadvantage others; the very framing of the issues eliminates some ways of seeing the question.

Another argument against gene patenting rests on the notion that the human genome is part of our common human heritage. As such, the genome should be seen as public property and no single person, organization, or group should have the right to exclude others from access to public property. Native Americans, in spite of their diversity of religious and ethical views, generally oppose gene patenting, seeing it as a new form of *biopiracy* in which colonizers steal from natives anything of value. Serious issues of international justice are raised by such concerns.

In the popular mind, gene patenting is linked with practices such as buying and selling of human body parts. Hence, gene patenting evokes prohibitions against ownership of human beings. If parts of a body can be owned, then there is no reason that all the parts could not be owned, resulting in the ownership of persons. Prohibitions against buying and selling body parts or owning persons exist worldwide. In the West in particular, early Christian belief in a literal resurrection of the body continues today, as Paul Rabinow states, in an "enduring cultural understanding that the 'person' is inextricably tied to the sheer materiality of the body or its parts . . . ." (p. 185). To patent human genes is thus perceived as patenting persons, which is repugnant to many. One critic argues that current patent law in the United States would permit patenting processes for germline genetic intervention, thus leading to rights over a genetically altered human being. The shared presumption that people cannot be owned thus generates some resistance to patenting of human genes.

Even those who do not utilize explicitly religious arguments often wish to set bodies and body parts aside as something that cannot be owned or patented. The European Union Directive of 1998 states that the human body "and the simple discovery of one of its elements, including the sequence of a gene, cannot constitute patentable inventions." Similarly, lawyer and bioethicist George Annas has argued strongly against any "ownership" of human body parts.

Arguments for gene patenting

Proponents of gene patenting counter that patents are not granted on humans or their bodies, but only on genes or gene fragments. More importantly, what is patented is in the laboratory, not in the living person; holding a patent on a gene does not grant ownership of the gene inside someone's body. For example, Article 5(2) of the European Union Directive does permit patenting of gene sequences that are "isolated from" the body or produced by a technical process, provided their industrial application is disclosed. Here, the Directive balances the conviction that life forms per se should not be patentable with the reality that in the contemporary international market access to patents may be crucial for scientists and investors.

Two major arguments are proffered for gene patenting. First, such patents are part of the *intellectual property rights* tradition in which people have rights over things they have invented. Article 27 of the Universal Declaration of Human Rights specifically provides that every person has a right to "protection of the moral and material interests resulting from any scientific . . . production of which he is the author." The notion that there is a *right* of ownership deriving from authorship has deep roots. Seventeenth-century philosopher John Locke held that each person had a "property" in his own person and therefore in the work of his hands; by "mixing his labor" with objects (within certain constraints), a person gained a property right in those objects. This labor theory of property forms the basis for a deeply held conviction that patents are justified because they embody a right to the work of one's hands or one's mind.

However, under contemporary conditions, the one who discovered a gene may not hold the patent. More often, the patent holder is an employing institution or corporation that sponsors the research. Hence, the notion that there is a right to the work of one's hands or mind applies only ambiguously to the modern circumstances of gene patenting.

The second and more prominent argument for patenting genes and DNA fragments is a utilitarian one: patents, as William Haseltine writes, "ensure the rapid and open dissemination of new knowledge, encourage innovation, and promote commerce" (p. 59). Since patents are granted only where there is full disclosure of the invention, patents promote open dissemination of knowledge. Since they exclude others from using the invention, they provide time for commercial developments and thus encourage innovation. These are typical arguments made in the biotechnology industry.

Whether the patenting system has these good effects is difficult to ascertain. Both the Council for Responsible Genetics and the Human Genome Organization (HUGO), representing the coordinated mapping and sequencing efforts of many scientists worldwide, assert that patents work against the tradition of shared knowledge among researchers. The current climate of collaboration between universities and private industry raises particular concerns that patenting may not encourage open sharing of information but rather discourage it in the interests of developing commercial applications. Patent holders often permit free access to information for those doing basic research but restrict access for those doing applied research with commercial potential. In light of these and other considerations, some urge a moratorium on any further gene patenting. Others argue that even if patenting does contribute to the free flow of information, stimulate innovation, and promote commerce, these good effects must be balanced by principles of international justice and the common good, which might require some limitations on gene patenting.

See also BIOTECHNOLOGY; CREATION; DNA; GENETICS; HUMAN GENOME PROJECT

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KAREN LEBACQZ

GENERAL THEORY OF RELATIVITY

See RELATIVITY, GENERAL THEORY OF

GENESIS

The importance of the Old Testament book of Genesis in the history of science stems largely from the fact that the narrative begins with an account of creation. A wide variety of theological cosmologies were based on differing interpretations of these few verses. Most of these views hinged on two major issues of interpretation: the nature of the "beginning" and the primordial materials described in Genesis 1:1–2; and the six "days" described in Genesis 1:4–2:3.

Interpretations of Genesis 1: 1–2 varied with the version of the Bible that was used. The Hebrew version begins with a relative clause: "In the beginning when God created the heavens and the earth, the earth was a formless void . . . ." (New Revised Standard Version), much like the parallel Hebrew construction in Genesis 2:4. So the Hebrew version of Genesis began with the primordial materials of formless earth, water, and darkness (Genesis 1:2). Various interpretations of this "beginning" were possible. Some rabbis accepted the inference that God began with a pre-existent chaos and then created an ordered cosmos (Genesis Rabbah 1:5). Others brought in texts like Proverbs 8:22–24 to demonstrate that God had created the water and the darkness and that the "beginning" of Genesis 1:1 was God's own wisdom as encoded in the Torah (Jubilees 2:2–3; Genesis Rabbah 1:1, 9). Still others argued that God must have created worlds before this one (Genesis Rabbah 3:7; 9:2).

Most Diaspora Jews and early Christians, however, used the Greek translation of the Old Testament, known as the *Septuagint.* This text begins with the absolute statement: "In the beginning God created the heavens and the earth," which implied an absolute beginning for this universe. It also implied that the unformed earth and water were included in the initial act of creation. This reading was followed by pioneering theologians like Basil of Caesarea (c. 329–379) and Augustine of Hippo (354–430) and became the standard interpretation for Christians.

The meaning of the six days of Genesis 1 was also debated. Some exegetes thought there was a temporal sequence of days without specifying their exact length (Jubilees 2:2; Genesis Rabbah 1:3). For those who accepted the idea of an absolute beginning, this implied that God created the cosmos in two stages: God made the building materials (unformed earth, water, etc.) at the beginning of the first day; then God illuminated and formed those materials as described in the narrative (Wisdom of Solomon 11:17; 4 Ezra 6:38–40; Justin Martyr).

Others exegetes saw inconsistencies in the idea of a temporal sequence of days. For example, the first "day" that is described is assigned a cardinal number ("one day" rather than "first day," Genesis 1:5) in both the Hebrew and Greek versions (Genesis Rabbah 2:3; 3:9; Basil); the sun, moon, and stars appear in the narrative three days after the first evening and morning. Some Rabbis saw a nontemporal parallelism between the first three and the second three days (Genesis Rabbah 12:5). Others suggested that the ten utterances ("God said") of the narrative were patterned after the Ten Commandments or the construction of the Tabernacle (Pirqei Avot 5:1; Midrash Tanhuma). Other scholars argued that divine creation required no effort (Genesis Rabbah 12:10) and that it all might have taken place in a single instant (Philo; Midrash Tanhuma). This idea of a simultaneous creation of all things was followed by early Christian theologians like Origen (c. 185–254), Athanasius (c. 293–373), Basil, and Augustine.

See also COSMOLOGY, RELIGIOUS AND PHILOSOPHICAL ASPECTS; CREATIO EX NIHILO; LIFE, ORIGINS OF

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GENE THERAPY

Gene therapy refers to the repairing or replacing of malfunctioning genes that cause a deleterious illness or condition. There are two forms of gene therapy: *somatic* and *germline.*

Somatic and germline therapies

Somatic therapies are used to replace or repair malfunctioning genes that are expressed in such conditions as cystic fibrosis or sickle cell disease. Since these therapies attempt to remedy the causes rather than alleviate the effects of disease, they presumably will provide more effective and beneficial medical treatments. Although initial attempts to develop somatic gene therapies proved largely unsuccessful, experimental treatments since the mid 1990s of severe combined immunodeficiency disease (SCID) and sickle cell disease have renewed public optimism regarding its potential efficacy.

Like somatic therapies, germline therapies attempt to repair or replace malfunctioning genes. The principal difference is that the corrected gene, rather than the deleterious one, is passed-on to subsequent generations. Consequently, the potential benefits or effects of germline therapies could be much more widespread than those of somatic therapies. As of 2002, no experimental procedures employing human germline techniques had been undertaken.

Ethical and moral objections

In principle, somatic gene therapy has raised few ethical objections. Because these therapies treat the underlying causes of disease at the molecular level rather than concentrating on affected organs or compromised biological processes, somatic therapies have been largely perceived as more sophisticated and potentially more effective extensions of established medical procedures. So long as these therapies are safe, there is nothing inherently wrong in deploying them. The issue of safety, however, came to the forefront with the death in 1999 of a patient undergoing an experimental genetic treatment for ornithine transcarbamylase (OTC) deficiency, an incident that prompted calls for greater public oversight or regulation.

The prospect of germline therapy has proven much more controversial. The primary objection is that humans should not attempt to construct the genetic inheritance of future generations. This objection usually takes one of two forms. First, since so little is known about the complex relationship between genes and larger environmental factors, it would be imprudent to introduce genetic alterations that would be inherited by future generations. Although the goal would be to eliminate a severely debilitating disease or condition, there might be unintended or unforeseen consequences that would adversely affect subsequent generations. Individuals carrying a recessive deleterious gene, for example, might in the future incur certain survival advantages in response to changing environmental factors. Since the effects of germline therapy are so much more widespread than those of somatic therapies, large populations could be potentially devastated. The seemingly harmless or even beneficial intervention into the human germline could wreak havoc down the road.

The second form of this objection invokes a more sweeping moral imperative. Humans do not have a right to shape the genetic endowment of their descendants, and correspondingly, individuals have the right to be born with unaltered genomes. People must simply resist the temptation to play God in shaping the destiny of humans, both as individuals and as a species.

The principal defense against this objection, in both its forms, is that it does not sufficiently take into account the nature of evolutionary change, thereby imposing unwarranted responsibilities regarding the possible fate of future generations. Other than identical twins, there are no unique genomes that parents do not have a right to alter or that offspring have a right to inherit in an unaltered form. Human reproduction entails the creation of a unique genome, derived from the genes of parents but also including mutations. It is difficult to imagine what an unaltered genome might be in the future in evolutionary terms. If individuals have a right to inherit an unaltered genome, then presumably cloning should become the preferred method of human reproduction. In addition, many argue that the prudential claim that current ignorance should prohibit germline interventions is unwarranted. Every action entails unforeseen consequences, and it is not known whether failing to intervene will prove better or worse than intervening. It cannot be known in advance whether the consequences of germline therapies will be any more or less devastating than those of natural selection upon future generations.

Some religious and moral concerns have also been raised, not so much with the prospect of genetic therapy per se, but with the fear that their introduction might exacerbate some already troubling trends. For instance, it is argued that the growing knowledge of human genetics is not being used, at least initially, to develop more effective therapies, but to prevent the birth of offspring with debilitating or undesirable genetic traits. Some fear that parents will turn increasingly to embryonic testing and screening techniques, such as preimplantation genetic diagnosis, to prevent the implantation of embryos carrying certain genetic abnormalities, leading in turn to the destruction of embryos deemed to be undesirable.

The issue is further compounded because the same techniques being developed as therapies may also be applied to select, and perhaps someday enhance, certain genetic characteristics of offspring. The bar of parental expectation would then be raised dramatically regarding what constitutes a desirable or even healthy child. The prospect of so-called designer babies will exert social pressure on parents not only to prevent the birth of offspring with severely debilitating conditions, but to select or enhance their genetic endowment in the hope of giving their children the best possible start in life. Although the development of genetic therapy is motivated by a humane impulse, its advent could fuel parental anxieties and prejudicial attitudes toward individuals with physical and mental disabilities, thereby unwittingly supporting a new, implicit, and insidious form of eugenics.

Proponents of genetic therapy counter that these worries are both unfounded and inflammatory. Legal protections against discrimination can be enacted as needed. Moreover, the best way prevent the destruction of so-called undesirable embryos is to develop effective genetic therapies as quickly as possible. More importantly, the distinction between genetic therapy and genetic selection and enhancement is spurious. Any therapy is also an enhancement, because the restoration of health is presumably an improvement over illness. In addition, many non-genetic medical procedures are enhancing, rather than therapeutic, in character, and genetic therapies will make them more effective. Genetically enhancing an individual's immune system, for example, is merely a more effective form of inoculation. Despite the moral and religious objections, the development of effective gene therapies may alleviate the suffering of many people.

See also BIOTECHNOLOGY; DNA; ETHNICITY; EUGENICS; EVOLUTION; GENE THERAPY; GENETIC ENGINEERING; GENETIC TESTING; GENETICALLY MODIFIED ORGANISMS; GENETICS; HUMAN GENOME PROJECT; MUTATION; NATURE VERSUS NURTURE; PLAYING GOD; REPRODUCTIVE TECHNOLOGY

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GENETICALLY MODIFIED ORGANISMS

Humans have tried to influence the development of organisms for centuries by selectively breeding plants and animals. Advances in genetics make it possible to engineer organisms at the cellular level to improve everything from the productivity of crops to the viability of animal organs and tissues for transplantation to humans. There are basically two ways to genetically alter an organism: A *transgenic* animal has been modified by the introduction of a new gene, whereas a *knock out* is an animal in which a given gene is no longer expressed. Religious and ethical concerns include respect for the well being of future generations of the organisms and possible effects on the environment.

See also BIOTECHNOLOGY; DNA; GENE THERAPY; GENETIC DETERMINISM; GENETIC ENGINEERING; GENETICS; XENOTRANSPLANTATION

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GENETIC DEFECT

A genetic defect occurs when a gene fails to express a certain function or produce a particular protein. Such a defect may cause or be a contributing factor to a debilitating disease or illness. The defect occurs when DNA is miscopied, resulting in what geneticists call a *mutation*. It should be noted that virtually every human being carries a small number of mutations, but they usually are not expressed in a deleterious manner.

Mutations can be passed from parents to offspring. If only one parent carries a mutated gene it will usually be overridden by a second copy of the gene. If both parents carry the mutated genes, offspring are at risk of being affected. For example, if one parent carries the recessive gene for cystic fibrosis but the other parent does not, there is no risk that offspring will be afflicted with the disease. If both parents carry the recessive gene, however, there is a one-in-four chance that they will give birth to a child with cystic fibrosis. In addition, mutations can occur through exposure to certain levels of radiation or chemicals.

The term *genetic defect* is falling into disfavor because of its pejorative connotation. To identify a gene as "defective" implies that this determination is made in comparison to a natural, normative standard. Consequently, it suggests that individuals affected by defective genes are themselves defective or inferior human beings. A genetic "defect," however, denotes a statistical abnormality within a given population. The degree to which such an abnormality is judged to be defective is as much a social as it is a medical determination. Short stature, for example, is a "defect" only in a culture that places a high value on being tall.

A principal religious concern is to insure that individuals expressing certain genetic traits that are perceived to be undesirable are not stigmatized or subjected to unwarranted discrimination. A similar concern holds for parents of children with genetically related illnesses (particularly illnesses that could be prevented through embryonic or fetal testing), or communities in which there are high incidents of certain conditions such as sickle-cell anemia or Tay Sach's disease. Moreover, there is also some apprehension that recent advances in embryonic and fetal testing will promote a new and more subtle round of eugenics in which parents will select against offspring with genetic traits judged to be defective or undesirable. These religious concerns are derived from a conviction that the value or worth of an individual is not derived from the presence or absence of genetic characteristics, thereby implying a natural hierarchy among human beings.

The idea of a genetic defect also raises vexing theological questions. For instance, since mutations can be passed from parents to offspring, does this imply that nature is flawed and is itself in need of redemption? But if this is the case, what would a redeemed or perfected nature be like? Or, to the contrary, is the possibility of deleterious mutations the necessary price that must be paid in order to spur evolutionary development within the human species? But if this is true, what is one to make of a God who seemingly requires the suffering of individuals in order to promote the flourishing of the species?

See also GENETIC TESTING; GENETICS; MUTATION

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BRENT WATERS

GENETIC DETERMINISM

With rising public attention given to the Human Genome Project in the early 1990s, there grew an increased belief in genetic determinism. Scholars referred to this widespread belief variously as *geneticism,* the *strong genetic principle, genetic essentialism, genetic fatalism,* and the *gene myth.* Generic determinism was fed minimally by molecular biology but maximally by behavioral genetics and sociobiology. In the classic war between nature and nurture, genetic determinists sided with nature.

The gene myth can be dissected into three subtenets: puppet determinism, promethean determinism, and the commandment against playing God. The first is seemingly fatalistic; DNA defines human beings, and the genes, like a puppeteer, pull the strings that make people dance. The second, promethean determinism, assigns to scientists the task of understanding just how the genes work plus that of developing appropriate technologies based upon this understanding, giving humans control over what nature bequeaths. The third subtenet voices an ethical maxim: Thou shalt not play God. This sub-tenet derives from the Frankenstein fear of the mad scientist who, in trying to take control of the mysterious forces of life, oversteps the invisible boundary intended by nature to contain human pride and lets loose uncontrollable destructive forces.

See also BEHAVIORAL GENETICS; DETERMINISM; DNA; FREEDOM; GENETICS; HUMAN GENOME PROJECT; NATURE VERSUS NURTURE; SOCIOBIOLOGY

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TED PETERS

GENETIC ENGINEERING

The term *genetic engineering* refers to technologies that modify genes. Unlike selective breeding, which merely chooses traits that are already found in nature, genetic engineering acts directly on the genetic material itself in order to alter an organism's traits. Genetic engineering is the cornerstone of modern biotechnology, and through it human beings have the power to modify the molecular basis of all forms of life.

A brief history

The concept of genetic engineering emerged in the 1960s and was first realized in the 1970s. Its development depended upon a century of advances in science, beginning in the 1860s with Gregor

Mendel's discovery of the existence of factors that govern inheritance. In the 1940s, it was learned that these factors, now called *genes,* are composed of a complex molecule, deoxyribonucleic acid or DNA. In 1953, Francis Crick and James Watson described the structure of DNA as the famous double helix along which are found pairs of chemicals. Soon it was learned that the sequence of these chemicals, known as bases, carries information that instructs the cell how to make proteins that are essential to the structure and function of the cell.

By the 1960s, it was becoming clear that scientists would soon learn how to manipulate this chemical information and thereby engineer genes. In the ensuing decades, various techniques for manipulating DNA have been developed, beginning in the early 1970s with the discovery of the use of *restriction enzymes,* which exist in nature and which cut and join strands of DNA at precise locations. This allows scientists to cut and splice DNA. A later discovery called *polymerase chain reaction* (PCR) made it possible for researchers to produce huge quantities of specific DNA sequences. Further advances in the use of computers to decode, store, and manipulate DNA means that researchers can discover and modify DNA on a broad scale and with considerable precision.

Methods

Genetic engineering uses various methods in pursuit of many goals. One method is to transfer a gene from one organism to another. For instance a human gene may be transferred to a microorganism in order to develop a new strain of microorganism that will produce a human protein, such as insulin, for pharmaceutical purposes. Much of the insulin used by diabetics comes from this process. It is possible in fact to transfer many genes into an organism by packaging them together as a kind of artificial chromosome, sometimes called a *gene cassette.* Plants, too, are genetically engineered to produce pharmaceutical products, to enhance their protein value as foods, to allow them to grow with less reliance on pesticides or fertilizers, to resist freezing or spoiling, to enhance flavor, or perhaps to grow in seawater. Another method is to incapacitate a particular gene by deliberately causing it to mutate and shut itself down. For instance if scientists know that an impaired human gene is linked to a disease such as cancer, they will find the corresponding gene in laboratory rats, shut it down, and create a strain of rats with this gene knocked out, and therefore with a high likelihood for cancer, in order to have animals on which to test possible therapies.

In human beings, scientists have attempted to modify or replace genes in some of the cells of patients' bodies in order to treat diseases with genetic basis. This strategy, called *gene therapy,* began in 1990 with mixed success. In time it will likely become widely used to treat a variety of diseases. Still another method is to modify a tiny portion of the gene—one or two bases of DNA—by constructing a special small molecule that can trigger what is called a *mismatch repair.* Ordinarily the body corrects for the mutations that occur naturally inside the body all the time, and scientists are learning how to exploit the body's own repair mechanisms to correct mutations that may have been inherited. These strategies used so far on human beings differ sharply from what scientists are attempting to do with other animals. In human beings, researchers are attempting to change the genes only in selected cells that are affected by the disease. In animals, however, the modifications affect every cell and are passed on to future generations. That strategy, often called *germline modification,* has been proposed for use on human beings but remains controversial from the standpoint of safety.

Religious concerns

From the time genetic engineering was first considered in the 1960s, religious scholars and institutions have commented on its value and limits. Often scientists themselves, not to mention science journalists, report on developments in genetics in religious terms, speaking of DNA as the mystery of life or the human genome as the holy grail of biology. Not surprisingly, the general public sometimes responded to these developments with religious fervor, sometimes in favor of them, but often opposed to developments that people saw as, for instance, *playing God.*

One concern of special importance to many religious scholars and leaders has been the use of the system of patenting, by which governments give exclusive rights for a time to inventors, to protect developments in genetics. Particularly troubling has been the granting of patents to gene sequence information. Many have argued that knowledge of genes is discovery, not invention, and should not be eligible for patent protection. Many have also argued that granting biological patents amounts to patenting life, therefore making life a mere commodity. Other religious scholars recognize that patenting, while not perfect, is essential to the financial development of the full potential of genetic engineering, and that opposition to patenting is tantamount to opposing the benefits of research.

Beyond these general concerns, many religious scholars and organizations have considered developments in genetic engineering on a case-by-case basis. For instance, many religious organizations have responded to the use of genetic engineering to modify food by recognizing its potential for increasing the quality and quantity of food, but with cautions having to do with the viability of small farms, global inequities, the power of corporations in view of intellectual property rights, and the right of consumers to know what they are eating. Similarly, religious scholars have raised concerns, but generally have not objected categorically, to genetic engineering of animals. Of special concern is the prospect of herds of genetically identical livestock becoming vulnerable to disease, or to the use of genetic engineering to create strains of animals whose sole purpose is to suffer a disease for the benefit of medical research.

Quite understandably, human applications evoke the most intense religious responses. Religious responses to the use of genetic engineering for pharmaceutical purposes have been positive, with concerns limited to patenting, to the high costs of medicines, and to the need for socially just patterns of distribution. Furthermore, almost without exception, human gene therapy has met with approval not just by the public, but by religious institutions and scholars, who assess it morally as an extension of traditional medicine. Issues of safety remain, and many are concerned that the technique, when shown to be beneficial, will not be justly distributed.

The greatest concern, however, is that the technique will not be limited in its application to therapy but will be used for enhancement of human health and possibly of traits that are unrelated to health. Those who voice this concern point not just to cosmetic surgery and to performance enhancing drugs in sports but to the use of mood-altering pharmaceutical products, such as the drugs known as selective serotonin reuptake inhibitors (SSRIs). Evidence exists that people request these drugs not to treat anxiety or depression but to improve their mood and thus their performance in life. If that is true, some argue, how much more will people request gene modification that enhances their state of being and their performance. As of 2002, it is not at all clear which human traits will become susceptible to enhancement by genetic engineering. Height, most definitely, will be modifiable, but perhaps mental and emotional traits may be modifiable too. The concern here is the lack clarity about the distinction between therapy and enhancement, and thus the lack any publicly credible way to prevent those with economic or political means from acquiring new ways to improve themselves to the competitive disadvantage of others.

Sometime in the twenty-first century, many believe, humans will learn how to modify the genes of their offspring. Such germline modification, as it is usually called, is already done in other mammals, although not reliably. Many technical obstacles lie ahead, but learning to do this in human beings has a strong attraction, for some, in the promise that a family might be freed of a genetic disease that has afflicted it for generations. Other techniques, such as testing an embryo for disease before it is implanted, will probably achieve the same result at less cost and risk. If so, it may turn out that the real advantage of germline modification is not to eliminate disease but to improve the next generation, perhaps by enhancing resistance to disease or by producing other traits. The prospect of children born with such enhancement, often referred to as designer babies, is widely opposed by the general public, secular scholars, and religious leaders, even though most analysts concede that it probably cannot be prevented.

Religious objections to germline modification are that the resulting children will enter the world as objects, engineered according to the will of their designers and not as persons who emerge from the love of their parents. The intrusion of technology perverts the relationship between parent and child, difficult under any circumstance, but all the more so if parents can use technology to express their desires for the kind of child they want to have. Others believe that designed children will face impossible expectations in achieving that for which they are designed, and that they will likely resist their makers' intentions.

See also BIOTECHNOLOGY; CLONING; DNA; EUGENICS; GENE PATENTING; GENE THERAPY; GENETICALLY MODIFIED ORGANISMS; GENETICS; HUMAN GENOME PROJECT; PLAYING GOD; STEM CELL RESEARCH

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GENETIC FUTURISM

See GENETICS

GENETICS

Genetics is the field of scientific research that studies gene activity in plants, animals, and humans. Genes are segments of DNA (deoxyribonucleic acid) found in each living cell; each of these DNA segments codes for a protein, thereby yielding a phenotypic effect. All life on Earth shares the chemical make-up of DNA, even though each species differs in the number and function of genes. Scientists estimate that human DNA contains between thirty-one and thirty-six thousand genes arrayed over two pairs of twenty-three chromosomes. The forty-six human chromosomes are strands of DNA, with each of the twenty-three strand pairs arranged as a double helix. The DNA strands are composed of four base chemicals: adenine (*A*), guanine (*G*), cytosine (*C*), and thymine (*T*). These four bases are typically identified by their single letter abbreviations (*A,G,C,T*) and constitute an alphabet, so to speak, that carries genetic information from DNA to tissue formation and bodily activity.

Modern genetics began in the nineteenth century with the research of an obscure Austrian monk, Gregor Mendel (1822–1884), who discovered patterns of inheritance in pea plants. Mendelian laws of inheritance still stand as the foundation for contemporary genetics. The twentieth century added the chemical work of molecular biology, including the post World War II discovery of the double helix structure of DNA by James Watson (b. 1928) and Francis Crick (b. 1916). At the turn of the twenty-first century, the Human Genome Project had sequenced the three billion base pairs and nearly identified all the genes in the human genome. The complete genomes of a handful of plants and animals had also been identified.

In addition to molecular biology, which directly studies the chemical processes of genes, two other branches of genetics have become significant for religious reflection: behavioral genetics and sociobiology. Behavioral genetics employs statistical studies of phenotypical characteristics and social preferences to discern heritability probabilities. Central to such studies are monozygotic and heterozygotic twins raised apart. The assumption in such studies is that twins raised apart are excellent subjects because they provide opportunity to distinguish between genetic and environmental influences.

Sociobiology appeared in 1975 with publications by Harvard entomologist Edward O. Wilson (b. 1929). Wilson, having studied how ant societies are socially held together by chemical signals, purported by analogy that human breeding patterns, gender dominance, and caste systems are similarly explainable. Zoologist Richard Dawkins (b. 1941) shortly thereafter coined the term "selfish gene," which reinforced the central thesis of sociobiology. In Darwinian fashion the human organism does not live for itself; rather, its function in nature is to reproduce the genes for which it is the temporary carrier. In short, genetic forces drive evolution, including human evolution, and human social history, including religious history, can be explained by reference to genetic drives.

Theological issues raised by genetics

The apparent growth in knowledge regarding human nature cultivated by genetic research leads some religious thinkers to review their inherited anthropologies. Most theologians see the field of genetics as a challenge requiring response; a few see new genetic knowledge as a complement to long standing religious insight. Distinctively theological issues are few and are frequently embedded within the more plentiful and visible issues of ethics and public policy. Theological issues will be taken up immediately; ethical issues surrounding cloning and stem cell research will follow.

The first theological concern is *genetic reductionism.* Reductionism poses a theological threat everywhere in modern science. The form it takes in genetics is the vague cultural belief that "it's all in the genes." In the laboratory, methodological reductionism is necessary to foster research into gene function, but a threat comes with ontological reductionism and surmises that all of what constitutes human nature is reducible to the genes. During the early years of the Human Genome Project, DNA was described by some scientists as the "code of codes" or the "blueprint of humanity." Such biological reductionism seems to leave no room for independent influence on the part of spirit or culture, the dimensions wherein most religious traditions work.

A second and related concern is *genetic determinism.* If "it's all in the genes" and the DNA is the blueprint of who human beings are, then genes move into the position of determiners of human nature and human value. In the historical struggle between nature and nurture in the minds of intellectuals trying to explain human complexity, the new breed of genetic determinists stake their claim on nature. Relatively few molecular biologists advocate strong genetic determinism, whereas behavioral geneticists and sociobiologists reinforce it. Molecular biologists and philosophers who oppose an exclusive genetic determinism frequently appeal to two part determinism: genes plus environment. Some theologians locate human freedom in three part determinism: genes, environment, and the human self or person. In the latter case, the human self is emergent; the self is not reducible to either biological or environmental influences. Divine action in the human reality here is said to be holistic—that is, present to all three dimensions of biology, environment, and person.

A third and related concern is *neo-Darwinian evolution.* Nineteenth century Darwinism employed natural selection as the mechanism for explaining evolutionary change over time. Twentieth century neo-Darwinists such as Fransisco Ayala or Stephen Jay Gould add genetic mutation to the theory, adding detail to the manner in which natural selection works. Sociobiology extrapolates on neo-Darwinism by attempting to explain all of human culture including religious belief in terms of biological determinism. Sociobiologists (sometimes called evolutionary psychologists) contend that human culture is on a leash, a short leash, held by a genetic agenda. That agenda is the self-replication of genes using the human species as its vehicle. Human culture is structured so as to encourage reproduction and, hence, the perpetuation of genes. Human religion and human morality, whether theologians know it or not, is reducible to the agenda of selfish genes.

Those theologians who are attempting to incorporate sociobiology into their religious vision feel they must justify human transcendence of biology and the emergence of soul or spirit. Philip Hefner's theological anthropology, for example, argues that through evolutionary processes the genes have determined that we humans would be free. Some Christology's contend that Jesus marks a significant advance in evolutionary history, because with the Nazarene a precedent-setting life is led that transcends the selfish genetic agenda, and the possibility is opened for self-sacrificial loving. In contrast, some Muslim scholars find they must simply reject neo-Darwinian evolutionary theory because it makes no room for human spirit and because it fails to cohere with the anthropology of the Qur'an.

In summary, the theological community is accepting of the methodological reductionism within molecular biology that functions to yield advance in scientific research. However, theologians resist philosophical extrapolations that tend toward ontological reductionism or genetic determinism. Reductionism and determinism are insufficient, say theologians, to explain spiritual reality or ethical transcendence. Theologians defend human freedom and moral transcendence whether it complements the science or requires abandoning the science.

Genetic engineering

Genetic engineering consists of selecting, inserting, or removing individual genes in order to manipulate the genome of an organism. In agriculture and animal husbandry selective breeding to obtain preferred strains has been practiced for millennia. Modern genetic engineering adds chemical and mechanical methods for more sophisticated results.

In agriculture the genomes of plants are altered by genetic engineering to confer resistance to blight or resistance to herbicides in order to eliminate weeds while preserving the crops. Tomato genomes, for example, can be modified so as to stall final ripening during transport to market and then ripen just prior to going on sale. Such techniques dramatically increase the percentage of produce that becomes marketable. In Europe and other parts of the world popular movements against *genetically modified foods* (GMFs) have arisen. Fearing unknown possible health effects, opponents of GMFs lobby for accurate labeling so that the market can freely choose whether to consume them or not.

The engineering of farm animal genomes has two purposes. One is to obtain preferred strains of livestock, especially beef cattle. The other is to produce foods or pharmaceuticals for human consumption. An example of the latter case is the insertion of a human gene into a sheep genome to produce in the animal's milk a certain protein usable for treatment of a human disease. This use of animals for human betterment is itself controversial, with opponents arguing that turning animals into a means for human ends violates animal dignity.

To date, the genetic engineering of human genomes in the reproduction process has been limited to gene selection; it has not included gene insertion or removal. When in vitro multiple fertilized ova are examined, only those with the preferred genome may be implanted in the mother's uterus. This process is typically employed to eliminate known deleterious genes such as that for cystic fibrosis. In somatic therapy on living persons, however, more than selection is being tried. Genes that produce healthy blood have been inserted into bone marrow cells. Attempts are being made to send "knock out" genes into cancer tumors to turn off tumor growth by turning off telomerase activity.

An implicit theological issue that arises more often in the wider cultural debate than within specific religious communities is *naturalism.* Naturalism is the belief that nature apart from intervention by human technology is the source of value. Genetic engineering is a form of technology that alters the natural world people have inherited from evolutionary history. The promethean question arises implicitly: Is the natural world the source of human value, or, on the basis of humanly superimposed purposes, do people have the right to manipulate nature to meet these purposes? Much of the energy driving opposition to GMFs derives from naturalism. A similar naturalism is implicit in theological arguments, which presume that God's will is manifest in the genetic lottery resulting from sexual intercourse rather than through deliberate selection in vitro of the genetic code of future children.

The promethean question also arises with genetic futurism. As the present generation manipulates plant, animal, and human genomes, will this place humans in the position of guiding our evolutionary future? Does the human race possess the wisdom to choose a wholesome future or, like Prometheus of ancient Greek tragedy, will humans overstep their finite bounds and create an irreparable tragedy? Conservative theologians along with naturalist advocacy groups wish to put the brakes on genetic engineering and let nature take its course; whereas other religious leaders foresee immense benefits for health and wellbeing to be gained through genetic technology and contend that the human race must steward scientific advance.

Cloning

The two most virulent ethical controversies over genetic research have been cloning and stem cells. The two are linked. The first successful experiment in reproductive animal cloning was accomplished at the Roslin Institute in Edinburgh, Scotland, where embryologist Ian Wilmut cloned the world famous sheep, Dolly. The details were published in the February 27, 1997, issue of *Nature.* Wilmut's Roslin team removed cells from the udder of a pregnant Finn Dorset ewe, placed them in a culture, and starved them of serum nutrients for a week until the cells became quiescent—that is, they arrested the normal cycle of cell division, inviting a state akin to hibernation. Second, they took an unfertilized egg, or oocyte, from a Scottish Blackface ewe and removed the nucleus. When removing the nucleus with the DNA, they left the remaining cytoplasm intact. Third, the scientists placed the quiescent cell next to the oocyte; then they introduced pulses of electric current. The gentle electric shock caused the cells to fuse, and the oocyte cytoplasm accepted the quiescent DNA. A second electric pulse initiated normal cell division. Fourth, after six days of cell division, the merged embryo was implanted into the uterus of another Blackface ewe and brought through pregnancy to birth on July 5, 1996. The newborn babe was named Dolly. The procedure was called *somatic cell nuclear transfer* (NT).

An important scientific question was answered with this experiment: Is cell differentiation reversible? The answer seems to be yes. Embryonic cells are predifferentiated. Adult cells are normally differentiated in order to perform the particular tasks of particular parts of the body. For example, genes for hair are turned on in the hair while genes for toenails are turned off in hair but on where the toenails belong. In theory, cloning could be accomplished by employing embryonic cells in their predifferentiated state. The accomplishment here was to make an adult differentiated cell function as an undifferentiated embryonic cell.

The procedure was not clean and easy. The successful cloning of Dolly was accompanied by numerous misfires. Out of 277 tries, the Roslin scientists were able to make only twenty-nine embryos survive beyond six days. At fourteen days 62 percent of the fetuses in ewe wombs were lost, a significantly greater proportion than the estimate of 6 percent after natural mating. Eight ewes gave birth to five lambs, with all but one dying shortly thereafter. Dolly was the only one to survive. Triumph is accompanied by loss. Noting this, many scientists including Wilmut himself have opposed the prospect of human cloning because of the safety argument—that is, until the process is perfected, too many human embryos would be destroyed as misfires.

Ethical issues raised by cloning

Ethical issues arising from cloning technology can be divided into two areas, human reproductive cloning and human therapeutic cloning. Therapeutic cloning will be taken up later in the discussion of stem cells. The public discussion over reproductive cloning seems to focus on human reproduction, not animals. Cloned cattle and sheep do not elicit the religious opposition connected to human births.

The overriding ethical issue is this: Should human beings be cloned? Back in 1971 James Watson predicted this debate. Watson, along with Francis Crick, won the 1962 Nobel Prize for medicine or physiology for the discovery of the double helix structure of DNA. Writing on cloning for the May 1971 issue of the *Atlantic,* Watson predicted that the first reaction of most people to the arrival of these asexually produced children would be one of despair. He then went on to suggest that people with strong religious backgrounds would want to de-emphasize all those forms of research that would circumvent the normal sexual reproductive process. The Watson prophecy seems to have found its fulfillment.

In a February 22, 1997, press release, Donald Bruce, Director of the Society, Religion and Technology Project of the Church of Scotland, said that cloning human beings would be ethically unacceptable as a matter of principle. According to Christian belief, he said, cloning would be a violation of the uniqueness of human life, which God has given to each of us and to no one else. The argument that each individual person has a unique identity that would be violated by cloning has been repeated in religious and secular circles with a high degree of frequency.

The structure of this argument applies three assumptions to the issue of cloning. The first assumption is that in order for a human person to have an individual identity he or she must have a unique genome. The second assumption is that God has ordained that each person have a genome that differs from every other person. The third assumption is that through this genetic technology human beings could accidentally produce two persons with the same identity and, thereby, violate the divine creator's intention. On the basis of these scientific and theological assumptions, the ethical conclusion drawn here is this: no cloning.

Those holding the alternative position reject these assumptions. Scientifically speaking, even though two individuals might end up with identical genotypes, they would not end up with identical phenotypes. DNA does not always express itself in lock step fashion. There are variations in expression and spontaneous mutations. In addition, environmental factors such as food and exercise and health care influence gene activity. If the DNA donor and clone are reared a generation apart in time let alone in separate locations, similarities will be noticeable, but differences will abound.

The existence of monozygotic twins is instructive. Like clones, identical twins are born with identical genomes. Despite what they share in common, they grow up as separate and distinct individuals. Each has his or her own interior consciousness, sense of self, thought processes, and ethical responsibility. Even if studies in behavioral genetics eventually show strong DNA influence on predispositions to certain forms of behavior, they remain two separate individuals with separate lives to lead. A clone would in effect be a delayed twin; due to the delay, a clone would probably experience even more independence than two born at the same time.

During the debate, the question arose: Would two clones share a single soul? No theological position to date has held that two twins share a single soul. Each has his or her own soul, his or her own connection to God. This by analogy would seem to apply to clones as well. The human soul, theologically speaking, is not formed from DNA as the phenotype is formed from the genotype. The soul is not a metaphysical appendage to the physical. In sum, the theological argument against cloning based on an alleged violation of a God-given identity appeared early in the debate but eventually dissipated under critical review.

The United States National Bioethics Advisory Commission (NBAC) studied cloning—a study that included interviews with leaders in Judaism, Islam, Hinduism, Buddhism, Evangelical Protestantism, Liberal Protestantism, and Roman Catholicism—and issued a report on June 6, 1997, with the following conclusion: At this time it is morally unacceptable for anyone in the public or private sector, whether in a research or clinical setting, to attempt to create a child using somatic cell nuclear transfer cloning. The principle argument against cloning was the safety argument, as enunciated above by Ian Wilmut. The report went on to ask the U.S. Congress to pass legislation setting a three to five year moratorium on the use of federal funding in support of human cloning, and it asked non-federally funded private sectors to comply voluntarily with this moratorium. The NBAC further recommended that religious groups carry on an ongoing discussion of the ethics of cloning. Even though legislation did not follow, religious groups have carried on the recommended discussion.

In addition to the safety and the identity arguments, a third has been raised against human reproductive cloning: the commodification argument. Cloning—as a form of designer baby making—might lead to the commodification or commercialization of children; this would constitute an assault on a child's dignity. Dignity in this case is not based upon genetic individuality but upon treatment as an end rather than a means. Designer babies serve the ends of the designers, the parents, not the ends of the child. Cloning along with other genetic technologies, critics fear, may play into the hands of economic forces that will tend to commodify newborn children. Commodification, not genetic uniqueness, would deny the sacred character of human individual life.

Stem cells

The cloning controversy deals primarily with human reproduction. The stem cell controversy moves into therapeutic cloning and related matters. The therapeutic promise is dramatic. Specifically, rejuvenation through transplantation of tissue grown in a laboratory from stem cells would be of enormous value for *cardiomyocytes* to renew heart muscle to prevent congestive heart failure; replacement of *hematopoietic stem cells* for producing healthy blood in bone marrow to resist infection by the HIV virus and to treat AIDS and possibly sickle cell anemia; cultivating *endothelial cells* to reline blood vessels as treatment for atherosclerosis, angina, and stroke due to arterial insufficiency; rejuvenating *islet cells* in the pancreas to produce natural insulin to fight diabetes; renewal of *neurons* in the brain to treat Parkinson's disease and victims of stroke; *fibroblast* and *keratinocyte cells* to heal skin in the treatment of burns; and *chondrocytes* or cartilage cells to treat osteoarthritis or rheumatoid arthritis. All this promise arises from human embryonic stem cells (hES cells), which are self-renewing—virtually immortal—and have the capacity to develop into any or all tissue types in the human body.

Two momentous laboratory discoveries are relevant. First is the isolation of human embryonic stem cells (hES cells) in August 1998 by James Thomson, an associate veterinarian in the University of Wisconsin's Regional Primate Research Center. Thomson began with fertilized ova—spare embryos from in vitro fertilization (IVF) not placed in a uterus—and cultured them to the blastocyst stage, about four to six days. At this point he removed the outer shell of the blastocyst, separated out the individual cells, and placed them on a feeder tray. The cells divided. They reproduced themselves. Because these cells are as yet undifferentiated—that is, they are pluripotent and able to make any part of a human body—they are the cells from which other cells stem. Because they replicate themselves indefinitely, Thomson in effect created an immortal line of embryonic stem cells.

Second, John Gearhart, a professor of gynecology and obstetrics at Johns Hopkins University School of Medicine, drew human embryonic germ cells (hEG cells) from fetal gonadal tissue in September 1998. These cells, when taken from an aborted fetus, resemble in nearly all respects the pluripotent stem cells described above.

It is not yet clear whether or not hES cells are identical to hEG. Both are pluripotent and equivalent in function. Yet, it may be discovered that different alleles appear in different hES, because hES cells could be imprinted by either the male or female source. The blastocyst stage of embryogenesis is a stage that avoids the gender imprint. What is not yet known is whether original gender imprint will matter. For the foreseeable future the two types of stem cells will be treated the same, yet controversy rages over Thomson's destruction of the blastocyst to obtain hES cells.

One goal of the research agenda is to learn just what turns genes on and off. Once scientists have gained the knowledge of triggering gene expression, they can apply it to pluripotent stem cells and direct the growth of selected bodily tissue. Particular organs could be grown in culture. Heart tissue or entire organs such as the pancreas or liver could be grown in the laboratory. These would be healthy rejuvenating organs ready for transplantation.

In order to transplant the laboratory grown organs, however, medical scientists need to override our immune system in order to avoid organ rejection. Two scenarios lie before us. One would be to create a *universal donor* cell that would be compatible with any organ recipient. The task here would be to disrupt or alter the genes within the cell responsible for the proteins on the cell's outer surface that label them as foreign to the recipient's immune system. This approach would be difficult. It would involve disrupting genes within the same DNA in which researchers are trying to express certain other genes. Exposing such cells to harsh conditions with rounds of different drugs may damage more than just the targeted surface proteins.

A preferable second scenario would be to make cells that are genetically compatible (histocompatible) with the organ recipient—that is, to make cells with an identical genotype. If the organ genotype matches that of the recipient, no immune system rejection will take place.

This is the connection to cloning, or somatic cell nuclear transfer. One hypothetical scenario is to begin with an enucleated human oocyte, an egg with the DNA nucleus removed. Via somatic nuclear transplantation—cloning—one could insert the DNA nucleus of the future transplant recipient. By turning on selected genes, selected tissue could be grown *ex vivo,* outside the body, and then through surgery placed within the recipient. Because the implanted heart or liver tissue has the same genetic code as the recipient, no rejection would occur. This is in part the Dolly scenario, although it differs in that it grows only organ tissue and not an entire fetus.

Another variant or second scenario distinguishes itself sharply from Dolly, namely, one that eliminates the use of a fresh oocyte. Instead of an oocyte, the recipient's DNA nucleus would be placed in a non-egg cell, in the stem cell itself. The goal here would be to accomplish laboratory organ growth in a stem cell that is not an egg. To accomplish this, further research on cytoplasm's role in gene expression is required, as well as development of the nuclear transfer technology for insertion into the tiny stem cell.

Ethical issues raised by stem cells

On August 9, 2001, U.S. President George W. Bush announced that his government would support research on existing lines of stem cells, but would refrain from supporting the destruction of embryos to create new cell lines. The president thought he was settling an ethical dispute. Public policy, science, and ethics are inextricable.

Formulating the central ethical question raised by stem cell research is difficult because each of the two sides is oriented toward a different question. The *embryo protection* position begins with the question: How can we protect the dignity of the embryo? The *beneficence* or healing opportunity position begins with the question: How can scientific research lead to advances in human health and well-being? Each position is internally coherent, yet they are locked in controversy.

Those holding the embryo protection position lift their voices in defense of the apparently helpless embryo threatened with death at the hands of the laboratory executioner. The use of blastocysts and aborted fetuses leads opponents to criticize the scientific community for devaluing human life. They argue that the devaluation of humans at the very commencement of life encourages a policy of sacrificing the vulnerable, and this could ultimately put other humans at risk, such as those with disabilities and the aged, through a new eugenics of euthanasia. Pope John Paul II (1978–), in an elocution at Castel Gandolpho in August 2001, likened the destruction of blastocysts to obtain hES cells with infanticide. In effect, the embryo protection position sees the stem cell debate in terms of the abortion debate.

The major premise of this position is that each human embryo is the tiniest of human beings. The unspoken second premise is that, because an embryonic stem cell is a tiny human being, it has dignity. And, having dignity, the embryo providing the stem cell deserves protection from scientists who would use the name of medical research to destroy it. The nonmalificence or "do no harm" medical maxim applies here, and this maxim is violated in embryonic stem cell research.

In contrast, the healing opportunity position notes that the principle of beneficence goes beyond that of nonmalificence. Beyond avoiding harm, appeal to beneficence requires the active pursuit of human health and wellbeing. The central focus here is the good promised by stem cell research. Beneficence is a form of *agape,* selfless love. Decisive in the thinking of Christian supporters of medical research is Jesus' own ministry of healing, which set an example for his disciples. In many cities Christian groups have named their hospitals "Good Samaritan" after the key figure in one of Jesus' parables who administered healing to an abandoned victim of violence. From this perspective, secular medical research contributes to God's healing work on earth.

Embryo protectors accuse beneficence supporters of crass utilitarianism, of sacrificing innocent human beings in vitro for future hospital patients. Stem cell supporters repudiate the charge of utilitarianism, some even conceding the possibility of dignity applied to the early embryo. Relevant here is the observation that hES cells are derived from surplus embryos, from fertilized ova discarded in clinics. Such surplus embryos are slated for destruction in any case, either due to freezer burn or overt disposal. The beneficence position does not necessarily endorse the actual creation of new embryos for sacrifice to laboratory research; rather, it is satisfied with drawing some life-giving potential from an entity otherwise marked for disposal. Rather than deny dignity to the early embryo, beneficence advocates believe they can affirm embryo dignity yet still sustain justification for proceeding with health yielding research on stem cells.

The deliberate creation of fresh embryos for destruction in the laboratory would require an additional premise to attain ethical justification. The additional premise could be supplied by the developmentalists. Ethicists holding the developmentalist position frequently apply the fourteen-day rule. This is based on the observation that until an embryo attaches itself to the uterine wall and gastrulation occurs, a single individual fetus is not yet formed. Twining can still occur up until the appearance of the primitive streak that will become the backbone, thereby defining a single individual rather than multiple fetuses. By denying individuality to the embryo prior to the fourteenth day, some ethicists justify research at prior stages of development. Stem cells are harvested between the fourth and sixth days.

The Vatican has steadfastly rejected the fourteen-day rule. *Donum Vitae* in 1987 and subsequent papal elocutions have reiterated the classic doctrine of creationism and applied it to the so-called moment of conception. When the sperm fertilizes the egg during sexual intercourse, says Pope John Paul II, a third factor is present. God imparts a freshly created soul to the zygote. The presence of this eternal soul establishes personhood and dignity to the embryo. This makes it morally inviolable and, hence, protectable.

Genetics, culture, and religion

With the field of genetics the unavoidable interpenetration of science, culture, and religion becomes visible. Laboratory researchers cannot separate their daily work from wider cultural interpretations, and the wider culture in this case has elected to interpret genes deterministically. Theologians, who represent the intellectual segment of religious traditions, find themselves simultaneously listening to the bench scientists and the wider cultural cacophony, trying to respond to both. The pressure is increased by the demand from the political sector to establish public policy regarding what is permissible in basic research and resulting medical technology. Society cannot do without either the scientists or the theologians.

See also BEHAVIORAL GENETICS; BIOTECHNOLOGY; CLONING; DNA; EUGENICS; FREEDOM; GENE THERAPY; GENETICALLY MODIFIED ORGANISMS; GENETIC DEFECT; GENETIC DETERMINISM; GENETIC ENGINEERING; GENETIC TESTING; HUMAN GENOME PROJECT; MEMES; MUTATION; NATURALISM; NATURE VERSUS NURTURE; SELFISH GENE; SOCIOBIOLOGY; STEM CELL RESEARCH

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TED PETERS

GENETIC TESTING

Advances in the science of human genetics since 1980 (particularly the Human Genome Project) have prompted the development of techniques that identify a growing range of deleterious traits or predispositions. As researchers gain greater knowledge about the genetic components of many diseases or disorders, individuals are enabled to take precautionary measures reducing the chances of contracting an illness or mitigating its effects. In addition, genetic testing may be used to prevent the birth of offspring with a severely debilitating illness or disability.

Individuals, for example, may be tested for genetic traits indicating a proclivity for various forms of cancer or heart disease. If these genetic indications are present, individuals can avoid certain lifestyles or diets, take prescribed medications, or undergo invasive surgical techniques (in rare instances), which may help prevent the onset of cancer or heart disease. Moreover, individuals may also be tested for genetic abnormalities that may be passed on to offspring. Individuals may use this knowledge to inform their reproductive decisions. An individual carrying a recessive gene for cystic fibrosis, for instance, may avoid reproducing, limit mate selection to individuals not carrying the same recessive gene, or use a reproductive technology that employs donated gametes.

Genetic testing may also be used to prevent the birth of offspring with a debilitating illness or disability. Using amniocentesis or chorionic villus sampling, for example, a fetus can be tested for a genetically based condition such as Tay-Sachs syndrome. If the test is positive, parents may choose to prepare themselves to care for a terminally ill child or terminate the pregnancy. In addition, preimplantation genetic diagnosis in conjunction with in vitro fertilization may be employed to test a number of embryos, implanting only those that are unaffected by the deleterious gene.

As genetic testing becomes more sophisticated, it offers great promise for advances in diagnostic and preventive techniques. As the understanding of the complex relationship between genes and environmental factors increases, it is hoped that drugs can be developed that will prevent a wide range of late onset diseases. Some envision a day, for example, when individuals with a genetic predisposition for Alzheimer's disease will be able to take prescribed drugs preventing the onset of the disease, or at least mitigating its effects.

Although genetic testing undoubtedly benefits many people, it also raises a number of important ethical, pastoral, and religious issues. There are concerns over privacy. Some worry that genetic testing will be used to discriminate against individuals in employment or insurance coverage. There are concerns over the moral status of the fetus and embryo. Although prenatal testing may prevent the birth of children suffering from severely debilitating illnesses, the techniques also entail destruction of selected fetuses and embryos. More broadly, genetic testing raises intriguing implications for theological anthropology. How will a burgeoning knowledge of human genetics, as well as the ability to manipulate genes, inform religious accounts of what it means to be human?

See also BIOTECHNOLOGY; DNA; GENETIC DETERMINISM; GENETICS; HUMAN GENOME PROJECT; NATURE VERSUS NURTURE; SOCIOBIOLOGY

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BRENT WATERS

GEOCENTRISM

In geocentric worldviews, the earth is the center of the universe. The ancient Greek philosopher Aristotle (384–322 B.C.E.) thought of celestial bodies as beautiful and pure, travelling on the surface of perfect spheres, and of the earth as an imperfect place that had fallen to the center of the universe. In the second century B.C.E., Ptolemy adjusted the geocentric theory with *epicycles* (orbits imposed on the orbits of the planets) and *eccentrics* (orbits that were centered to the side of the universe) so that the theory was better able to predict the orbits of the sun, moon, and stars. The geocentric view of the universe was replaced by the heliocentric (sun-centered) view that was pioneered by Nicolaus Copernicus (1473–1543), adopted and defended by Galileo Galilei (1564–1642), and much refined by Johannes Kepler (1571–1630), who discovered the elliptical nature of planetary orbits.

See also ANTHROPOCENTISM; COSMOLOGY, PHYSICAL ASPECTS; GALILEO GALILEI

DENIS EDWARDS

GEOMETRY, MODERN: THEOLOGICAL ASPECTS

The discovery of mathematics in deep Antiquity, together with its essential pair, geometry, was an important factor shaping rationalistic tendencies of the European spirit. From Plato's belief that "God geometrizes" through Einstein's conviction that the goal of science is nothing else but "to discover the mind of God," interaction between geometry and theology continued with change a changing rate and intensity.

Middle Ages through the nineteenth century

During the Middle Ages theology formed the natural environment for the sciences. For instance, the shift in theology from the understanding of God's presence in the world in terms of "his power" to the understanding of his omnipresence in terms of "all places" fostered the gradual emergence of the modern idea of space extending to infinity. This process culminated with the French philosopher and mathematician René Descartes (1596–1650), who identified matter with only one of its attributes, extension: body is nothing but an extended thing. Descartes was doubtless inspired by his monumental discovery of analytic geometry—the first really important discovery in geometry after Euclid and Apollonius. In Descartes's view, science, which should be done "in a geometric manner" (*more geometrico*), is concerned with extended bodies, thus leaving to philosophy the realm of consciousness.

In the seventeenth century a kind of fusion occurred between science and theology (called *physico-theology*) to an extent unheard before. This is clearly seen, for instance, in the writings of Isaac Newton (1642–1727). In creating his concept of absolute space Newton was a direct successor of former disputes on God's omnipresence. Newtonian absolute space, which "in its own nature, without relation to anything external, remains always similar and immovable" (*Principia*; 1687), has three attributes: homogeneity, immobility, and infinity, which qualify it as both the universal arena for physical processes and the "sense organ" of God (*sensorium Dei*). The enormous successes of Newton's physics overshadowed his theology and only the former function of the Newtonian space continued to exercise its influence on subsequent generations of thinkers.

Newton's absolute space as an arena for physical processes constituted an inherent element of the mechanistic worldview, and it came as a shock when it turned out that Euclidean space is not the only possibility. The dispute concerning Euclid's "fifth postulate" lasted from antiquity. The question was whether the fifth postulate has to be accepted as an independent assumption or could be deduced from other postulates. Many proofs of the fifth postulate produced during the centuries invariably turned out to fail. Around 1830, three mathematicians—Nikolai Ivanovich Lobachevsky (1793–1856), Janos Bólyay (1802–1860), and Carl Friedrich Gauss (1777–1855)—demonstrated independently but almost simultaneously that one can obtain a new geometry, a geometry that is absolutely consistent from a logical point of view, based on the negation of Euclid's fifth postulate. This shows that Euclid was right: The fifth postulate is an independent assumption and cannot be derived from other postulates. This long expected conclusion was overshadowed, however, by the fact that a new non-Euclidean geometry was possible. Soon it became manifest that by playing with axioms an infinite number of geometries could be created. In fact, in the second half of the nineteenth century many new geometric systems were created and extensively explored. The philosophical significance of this mathematical revolution was comparable to that of Copernicus (1473–1543): Humans are not only creatures from the outskirts of the universe, but even the universe, at least conceptually, is not unique; it is a member of an infinite family of geometric universes.

German mathematician Georg Friedrich Bernhard Riemann (1826–1866) in his 1854 inaugural lecture created a broad conceptual setting for modern geometry, which admitted more than three spatial dimensions. He also foresaw its physical applications: The world, with all its physical fields, could be but a system of fluctuating geometries.

Relativity

At the end of the nineteenth century, peoples' imaginations were fed with multidimensional geometric pictures. Some philosophers started speculating on "other dimensions" as living places for spirits, and the popular writer Edwin A. Abbot published a book in 1884 entitled *Flatland,* the principal aim of which was criticism of Victorian England, but which in fact inspired both philosophers and scientists to deal with new geometric spaces.

With the advent of the special and general theories of relativity the concept of space-time entered the imaginary requisites of popular and philosophical literature and became a powerful tool of scientific investigation. From then on, geometry would not only deal with the problem of space but also with at least some aspects of the time problem. Consider only two such problems that have repercussions in theological matters. The first problem concerns the nature of time flow and its relationship to eternity. The theory of relativity favors, but does not require, a picture of space-time as existing in one totality with the idea of the flowing time being only a "projection" of human psychological experience onto the world. Such a picture is consonant with the traditional idea of God's eternity (going back to Augustine of Hippo [354–430 C.E.] and Boethius [c. 480–c. 526 C.E.]) as existence outside time rather than existence in time flowing from minus infinity to plus infinity. The second problem concerns the interpretation of the initial singularity appearing in some solutions of Einstein's equations describing the evolution of cosmological models. The question whether such a singularity (for instance the one corresponding to the Big Bang in the standard cosmological model) could be identified with God's act of creation was once heatedly discussed. The prevailing view at the start of the twenty-first century is that such interpretations should be postponed (if they are methodologically legitimate) until a trustworthy quantum cosmology becomes available

Rapid progress in relativity theory, especially during the second half of the twentieth century, greatly contributed to the development of geometry. New physical problems required the sharpening of known geometric methods and the invention of new ones. In fact, the necessity to consider more and more abstract spaces gradually led to the broadening of the notion of geometry itself. The process of the geometrization of physics has changed both physics and geometry.

Noncommutative geometry

It seems that a long dialogue between science and religion has made people more cautious about drawing theological conclusions from scientific premises, but there is still one lesson the theologian can learn from this process. The degree of generalization of spatial and temporal concepts one meets in geometry and its applications to physics is a good warning against anthropomorphisms in theological language.

One notable achievement in geometry at the end of the twentieth century is the creation and rapid progress in the so-called noncommutative geometry, which has some roots in the mathematical formalism of quantum mechanics. One of its aims is to deal with spaces that are intractable with the help of the usual geometric methods. Noncommutative spaces are, in general, purely global entities; no local concepts have, in general, any meaning. For example, the concept of point, as a typically local concept, has no meaning in many noncommutative spaces. The number of attempts to apply noncommutative geometry to physics, for instance to create a fundamental physical theory, is constantly increasing. Some such attempts can have a profound philosophical meaning. For example, it is possible to create a model of the fundamental physical level in which there is no space and no time in their usual senses (space consisting of points and time consisting of instants, which are local concepts) and yet, in spite of this, an authentic dynamics (i.e., equations modeling behavior of physical systems under the action of forces) can be defined in them. Even if such models will turn out to be false, they demonstrate, by being logically consistent, that time (in the usual sense as transient succession of events) is not the necessary condition for an authentic activity. This seems to falsify the claim of some theologians that the idea of an active agent existing outside the flow of time is contradictory in itself.

Conclusion

To conclude, it could be said that although in the past there were many direct influences coming from geometry to theology, it seems unlikely that this will happen in the future. However, one could expect an indirect influence. Modern geometric methods and their application to physics and other natural sciences doubtless shape people's sense of rationality, and this feeling for the rational will continue to be a powerful source of theological inspirations.

See also BIG BANG THEORY; EINSTEIN, ALBERT; MATHEMATICS; NEWTON, ISAAC; PHYSICS, QUANTUM; RELATIVITY, GENERAL THEORY OF; SINGULARITY; SPACE AND TIME

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GEOMETRY: PHILOSOPHICAL ASPECTS

The theological and religious importance of geometry needs to be addressed in conjunction with the much wider question of the relationship between those religious aspirations that strive to lay hold upon abstract eternal truths embedded and embodied in God and others that emphasize the importance of contingent, temporal, and ephemeral features of existence. To some extent this antithesis reflects the differences between the ancient Greek philosophers Plato (427–347 B.C.E.) and Aristotle (384–322 B.C.E.) in their attitudes toward the status of mathematical objects.

For Plato, neither geometrical objects such as points, lines, and circles, nor arithmetical objects such as numbers could be conceived as existing in the physical world. Since two shapes could not be the same, nor two objects equal, concepts such as shape and number had to belong to a realm beyond sense and experience, the realm of forms or ideas. Aristotle rejected this notion, preferring to think of geometrical and arithmetic objects as reductive abstractions from experience that give rise to mental generalities. During the Middle Ages, the Christian philosopher Thomas Aquinas was to make much of this in terms of intellective and abstractive knowledge, and in their turn John Duns Scotus (c. 1265–1308) and William of Ockham (c. 1285–1347) were to contribute to the debate by relating the issues to questions of universal and particular knowledge. Even so, the issue of the grounding of geometrical truth did not challenge the self-evident truth of Euclidean geometry; that had to await the advent of non-Euclidean geometries and the philosophical criticisms of John Stuart Mill (1806–1873) during the nineteenth century.

Euclidean geometry

Greek mathematics culminated around 300 B.C.E. in Euclid Alexandria's *Elements,* whose achievement was to treat geometry axiomatically through a rigorous system of deduction. This abstraction reflected the value placed upon eternal ideas by the platonic school, and rid geometry of reliance upon particular instances of such things as circles and lines. Euclid's achievement was to classify rather than discover the theorems he systematized. He was able to see that the entire edifice of geometry could be captured in a deductive system based upon five foundational assumptions or *postulates.* Granted those assumptions, no reference to the physical world was required, and the truths of the theorems he was able to deduce became tautological. Albert Einstein (1879–1955), writing long after the monopoly of Euclidean geometry had been broken, reiterated essentially the same point about the relationship between geometry and experience in his essay of that name where he observed that only one assumption is required in addition to a geometrical system: the further postulate that it is a model for the real world.

Whether the configuration and behavior of the physical world conforms to a deductive geometrical system is nonetheless an open question. If it does, there is a remarkable harmony between an abstract construction of the human mind and the workings of the world—part of what contemporary physicist Stephen Weinberg has called "the unreasonable effectiveness of mathematics," but the effectiveness of geometry may say more about the limitation and consistency of human thought and action than it does about the behavior of the world. As the Italian philosopher Giambattista Vico (1668–1744) put it in the *Nuovo Scienza* (New Science, 1725), the dilemma arises from the fundamental question of the relationship between the "found" and the "made" (*verum et factum*).

Euclidean geometry dominated mathematics for the subsequent two thousand years. Problems posed in antiquity that provided the stimuli for the development of enormous areas of mathematics—construction of a square with area exactly that of a given circle, the doubling of the volume of the altar at Delos, or the trisection of an angle (all to be solved using only straightedge and compasses)—remained unresolved until modern times, when all three were proved to be impossible. The influence of Euclidean geometry permeated education, architecture, science, and literature. The mediaeval *trivium* and *quadrivium* made geometry an essential ingredient of education. The Italian poet Dante Alighieri (1265–1321) designed the structure of Hell, Purgatory, and Heaven around it in his epic poem *The Divine Comedy.* First Ptolemy (C. 85–165 C.E.) and then Nicolaus Copernicus (1483–1543), Johannes Kepler (1571–1630), and Isaac Newton (1642–1727) devised their world systems upon it. Prohibition of images in Islam encouraged the intricate geometrical patterns used to decorate mosques.

Perhaps the most significant change in the study of geometry occurred with René Descartes's (1596–1650) invention of algebraic or *analytic* geometry as described in the *Discourse on Method* (1637) by envisaging geometrical figures superimposed on a grid, thereby making their properties susceptible to algebraic analysis. It is impossible to exaggerate the importance of this change, for it allowed geometry to be integrated into the calculus as discovered by Newton and Gottfried Wilhelm Leibniz (1646–1716), and so into the emerging theories of the physical world. Immanuel Kant (1724–1804) took it as an obvious a priori truth in the *Critique of Pure Reason* in 1781 that the sum of the angles of a triangle is 180 degrees, and Euclid continues to be taught throughout the world as a quintessential example of a deductive system to assess the potential of young mathematicians. Carl Friedrich Gauss (1777–1855), prompted by his study of curvature, was experimenting with alternative geometries, and the nineteenth century saw them proliferate through the work of Nikolai Ivanovitch Lobachevsky (1793–1856), Gauss's pupil Georg Friedrich Bernhard Riemann (1826–1866), and others.

Non-Euclidean geometries

From Euclid's own time there had been persistent attempts to deduce the "fifth postulate"—often cited as "through any point not in a given line one and only one line can be drawn parallel to the given line"—from the other four. These attempts continued until beyond Gauss's time, but he gradually became convinced that they were futile, that the fifth postulate was independent of the others, and therefore that it could be modified to produce non-Euclidean geometries. Lobachevsky was similarly obsessed with proving the fifth postulate, but, unlike Gauss, between 1826 and 1829 he worked on and eventually published his discovery of non-Euclidean geometry, thus dealing a blow to the Kantian system similar, as Carl Boyer puts it, to the impact on Pythagoreanism of the discovery of incommensurables. The "Copernicus of geometry," Lobachevsky was the first to generate an entirely consistent and coherent geometry that rejected Euclid's fifth postulate (although Janos Bólyay [1802–1860] also developed one almost simultaneously), but even he was so bemused by its counter-intuitive properties that he called it "imaginary" geometry. Non-Euclidean geometry nonetheless remained an obscure mathematical curiosity until taken up and generalized by Riemann. He realized that geometry need not be based upon quasi-Euclidean postulates at all, but could be regarded as a set of *n-tuples* (co-ordinates) combined according to certain rules. These rules define a *metric* and give rise to different kinds of Riemannian "space" governed by *tensors.* These spaces were to prove fundamental to the revolution in physics brought about by Einstein.

The realization that there were non-Euclidean geometries shook the foundations of mathematics and contributed to the demise of absolute foundationalism in philosophy, even though the discovery of different and mutually exclusive axiomatic geometries gave new momentum to the study of deductive systems based upon "foundations." Whereas for Kant and his predecessors there had seemed to be no element of choice in the determination of the geometry of the world because there was only one geometry, and that Euclid's, after Gauss and Lobachevsky it became necessary to add the postulate that Einstein was to remark on, that a particular geometry should also be chosen as the geometry of "real world." As he was to show in his theory of General Relativity, the "natural" geometry of the universe is not Euclidean at all, but Riemannian.

Implications for theology

In theological terms, the ubiquity and power of geometry have often been regarded as evidence for the work of God, whose mind has come on such a basis to be thought of as a perfect deductive system. But there are serious difficulties with such a view. One concerns the parallelism between deduction and determinism; another concerns the problem of the found and the made.

Deductive systems self-consciously avoid the introduction of any new material whatever; proof involves rendering explicit what is already implicit by applying the rules of deductive logic. A universe governed by physical laws equivalent to such deductive systems would be deterministic; there would quite literally be "no new thing under the sun" (Eccles. 1:9). At best, as occurs when implicit truths are rendered explicit by the articulation and proof of a new theorem in geometry, people would find themselves surprised by the unforeseen; but any freedom, either for God or for human beings, would be illusory, the outworking of an implicit and inevitable necessity.

Since Kant, people have been forced to take seriously the notion that what they regard as the intelligibility of the world is in reality the inner coherence of their modes of thought: in Vico's language, the intelligibility of the made, not the found. Objections to the employment of geometry as a model for the world reiterate this view in the context of doubts about the fine structure of the world and the limits of observation. Such doubts have been reinforced by the development of quantum mechanics and relativity, which suggest that human intuitions about the world are mistaken (although even these suggestions are still to be construed within a conceptual system, and not as grounded in a noumenal world).

Nonetheless, the expansion of elementary geometry into analytic geometry, topology, and linear algebra, preserves the sense of the "unreasonable effectiveness of mathematics," and suggests that, all doubts to the contrary notwithstanding, there may remain some sense in Newton's designation of the universe as the divine *sensorium,* albeit construed as a creation embodying the structure of a divine geometry, and intelligible only to a divine mind.

John Stuart Mill (1806–1873) was one of the first to challenge Kant's view that the a priori truths of geometry are necessary consequences of the possibility conditions of rational thought, in other words, that to be rational people have to think the world, amongst other things, in Euclidean terms. Mill did not know of non-Euclidean geometry, but attributed the apparent inescapability of Euclidean geometry to paucity of imagination, and its domination to the kinds of experiences to which human beings are susceptible. Mill seems to have been vindicated by the predilection of physical theory—in both quantum mechanics and relativity—for non-Euclidean geometries that defy everyday human intuitions.

Towards the end of the nineteenth century fundamental changes in philosophy of mathematics occurred, most notably the articulation of *logicism* by German mathematician and philosopher Gottlob Frege (1848–1925). Frege attempted to reduce arithmetic to logical categories by employing the theory of sets and the non-Euclidean geometries of Riemann that discard the intuitive notions of line and plane familiar from Euclid in favor of abstract *n-tuples* governed by arbitrary rules.

Attempts to reduce mathematics to logic were associated with Frege's attack on *psychologism,* itself a descendant of Kant's view that the nature of intelligible reality is governed not by properties of an objective world but by the rules of thought. Often called a modern platonism, Frege's work struggled to ground mathematics in an inviolable world independent of experience. Unfortunately, by adopting the theory of sets, Frege fell foul of Bertrand Russell's (1872–1970) celebrated paradox that the "set of all sets that are not members of themselves" both is and is not a member of itself, thus demonstrating that there is an apparent antinomy in the theory of sets.

Quite apart from its relevance to ontology and epistemology, and thus to theology, geometry has played a major role in the more everyday development of religion. Closely associated with the educated and priestly classes, with astronomy and astrology, with numerology and mysticism, geometry has repeatedly had an impact on the way people have viewed the order and mystery of the world. The Pythagoreans regarded number as the basis of all knowledge and truth, many religions and cults have seen mystical significance in the properties of geometrical shapes, especially the golden rectangle/ratio and the pentangle, widely employed in magic.

The fundamental religious importance of geometry nevertheless emerges from questions of the relationship between divine creative purpose, the structure and operation of the natural world, and the conceptual capacities of the human mind. If, as Einstein suggested, "the only unintelligible thing about the world is that it is intelligible," there seems to be an intrinsic harmony between all three, and geometry seems able, at least in the limit, to embody the structure of the world as found. If, as others suggest, following Kant, "the only intelligible thing about the world is that it is unintelligible," then geometry is a fabrication designed to render the world intelligible at the expense of misrepresenting its intrinsic structure, and geometry can do no more than embody a structure of the world as made in the image of the human mind.

See also KANT, IMMANUEL; MATHEMATICS; NEWTON, ISAAC; PHYSICS

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JOHN C. PUDDEFOOT

GERMLINE INTERVENTION

See GENE THERAPY

GLOBAL WARMING

Three important indicators suggest that the Earth's climate is going through a period of global warming: (1) an increase in atmospheric temperatures near the Earth's surface; (2) an increase in the surface temperature of the Earth's oceans; and (3) an increase in sea levels. Since global weather patterns are extraordinarily complex, with different systems influencing one another, the effects of global warming will vary from region to region. For instance, as global warming continues, some regions should have dramatic increases in annual precipitation levels, whereas other regions should have dramatic decreases—even desertification. Within the science and religion literature, discussions of global warming occur most frequently within ecological ethics. Ethicists draw from the climatology sciences to inform their reflection and analysis.

See also ECOLOGY; ECOLOGY, ETHICS OF; ECOLOGY, RELIGIOUS AND PHILOSOPHICAL ASPECTS; ECOLOGY, SCIENCE OF

RICHARD O. RANDOLPH

GOD

Taken in its subjective sense, the word *God* refers to whatever is the object of one's ultimate concern. Thus one might judge about a person, "Money or power is his god." But one can also ask whether his "god" really is God, whether what he treats as god possesses the properties one would expect in an object of ultimate concern. In this second or more objective sense, then, *God* refers to whatever is truly ultimate: the greatest being, the highest object of belief, the ground of all being. Most often, to believe in God means to believe that the ultimate reality is personal. That is, the divine possesses all the positive features that one associates with "mind" (intellect, will, self-consciousness, and perhaps emotions), but possesses them in an infinitely higher and more perfect form than humans do. For virtually all theists, God is understood as the creator of all things. For most theists, God is also understood as providentially involved in guiding the world subsequent to its creation.

Two major sources have added more specific content to the notion of God. The various religious traditions have developed extensive beliefs about the nature of God, the actions and self-revelation of God in the world, and the sorts of ethical and moral principles that most correspond to the divine nature. In a similar fashion, but not always in lockstep, the philosophical traditions have reached conclusions on what most appropriately count as attributes of God, how (if at all) the divine could be known, and why an infinite God could never be fully comprehended by finite knowers. Theologians have combined features from both of these approaches. They draw on beliefs from one or more of the religions, while analyzing and reformulating these beliefs using conclusions and conceptual tools developed by philosophers over the centuries. The result is a spectrum of positions on whether there are many gods or only one, on what it means to say that God is personal, and on how God is related to the world.

A brief history of God

Before there was belief in one God (monotheism), there was belief in many gods (polytheism). The earliest cultural remnants show humans relating to parts of the natural world (mountains, bodies of water, thunder and lightening, changes in climate) as if they were the product of personal forces. Finding reasons for natural events was perhaps the first step toward science, which gives explanations based on impersonal forces rather than on supernatural agents.

As cultures became more sophisticated, the gods took on personalities distinct from natural objects. Some of this evolution is visible in the Hebrew Bible, an authoritative text for Jewish, Christian, and Muslim views of God. Yahweh, the God of Abraham and his clan, was "a jealous God" (Exod. 20:5) who would allow "no other gods" before him (Deut. 5:7). Gradually the Israelites realized that Yahweh was "a great King above all gods" (Ps. 95:3), indeed so all-encompassing that there could be no other gods: "For I am God, and there is no other" (Isa. 45:22). Hence, the three Western monotheisms came to hold that God's power must be unlimited (omnipotence), as must be God's perception (omnipresence), God's knowledge (omniscience), and God's goodness (omnibenevolence). Yahweh must be the sole creator of all that is. All must stem from God, and God must have created all out of nothing (*creatio ex nihilo*). God became the ultimate ground and explanation of all things, the One who alone is worthy of worship.

In addition to this shared basis, the Western monotheisms also evidence important differences, regarding, for example, whether the divine nature is *trinitarian* (three-in-one) or not. Even if the full variety of specific beliefs about God cannot be treated in this entry, the differences remain vital for many believers. Indeed, many would resist the notion of "generic theism." That is, many would say that they are not believers in God in general but believers in "the God of Abraham, Isaac, and Jacob," or disciples of Allah as he revealed himself to the prophet Mohammed, or believers in the Holy Trinity of "God the Father, His Son Jesus Christ, and the Holy Spirit."

God and contemporary science

Some leading philosophers and scientists (for example, in the twentieth century, Bertrand Russell, Antony Flew, Edward O. Wilson, and Richard Dawkins) hold that belief in God as an explanatory principle is incompatible with science. Clearly, if science entails some form of metaphysical naturalism (physicalism, materialism, or nontheistic emergence), then all forms of theism are excluded; belief in a single act of divine creation would be no better off than the belief that one must sacrifice to the rain god. By contrast, other leading scientists are theists and find no conflict between their religious belief and the practice of science.

Among the latter group one finds stronger and weaker claims. For example, many hold that science and personalist theism are at least compatible and can coexist without contradiction or tension. Perhaps science explains the "how" of the universe, theism its ultimate "why." Perhaps divine actions concern only the "before" and "after," the moment of creation that led to the existence of physical laws and the final act that establishes "a new heaven and a new Earth" (Rev. 21:1). Or perhaps God-language refers to the ground of all existence and all value but can never be used to explain any particular thing or event.

Others make stronger claims: The order in the universe is best understood as an expression of the nature of God. Without God one cannot finally make sense of the lawfulness and mathematical simplicity of the physical world (John Polkinghorne), or of the evolution of intelligent life (theistic evolutionists and Intelligent Design theorists such as William Demski), or of human rationality and morality (Alvin Plantinga). It is argued that the fundamental physical constants are "fine-tuned" so as conjointly to make it possible, or even likely, that intelligent life would emerge, and that a supernatural agent offers the best explanation of this fact. To use Robert John Russell's distinction, they argue either that the universe is consistent with what the believer in God would expect (the theology of nature) or that the fine-tuning of physical constants actually provides evidence that God exists (natural theology).

Those who find science and theism in conflict suggest two different answers. One group responds that belief in God has to be eliminated, or at least radically modified so that it fits into the gaps left by science and makes no claims incompatible with it (the "god of the gaps"). For example, theistic language could be viewed as an expression of a cultural, emotional, or psychological particularity, similar to one's manner of dressing or speaking. If God-talk makes no truth claims, it cannot conflict with scientific results. Another group responds that the results and methods of science should instead be set aside whenever they conflict with theological truths. Religious fundamentalism may employ scientific-sounding language, as in "young Earth creationism"; it may refute science by appeal to scriptural texts; or it may associate God with "truths beyond the reach of reason" seen only through "the eyes of faith."

In summary, the differences in the logic of scientific theories and God-language are generally acknowledged. Proponents differ on whether the differences are tensions and, if so, how serious they are. Should the tensions be minimized, bringing science and religion into the greatest consonance possible, or should they be maximized, making the contrasts as stark as possible?

Issues on God and science

The God-science relationship has continually fascinated reflective persons for its alternating resonances and dissonances.

The problem of divine action. For Jews, Christians, and Muslims, God creates the world, sustains it in existence, and acts providentially to bring about divine purposes. Far from being deists, these traditions espoused miracles (supernatural interventions into history that set aside natural law). Indeed, the miracle of the resurrection lies at the center of Christian faith. But such miracles are by definition inaccessible to scientific study; indeed, they seem to imply the negation of scientific results and methods. Contemporary efforts to minimize the conflict include developing noninterventionist accounts of divine action in the world, reducing God's role to a single all-encompassing act, and offering fully naturalized reworkings of the traditional religions that eschew all miracle claims.

Evidences for and against God. Do human beings inhabit a cosmos that displays the signs of creation by a benevolent, omnipotent deity? Some say no. Vast regions are cold and uninhabitable; does all this exist just for the sake of intelligent animals on one planet? Entropy means the universe will wind down; what sign is there of "a new heaven and a new Earth"? Finally, why would a benevolent God allow such incredible evil, suffering, and wastefulness of life—both in the natural world and at the hands of man?

Others argue that the cosmos does display signs of creation by God. Could a random origin and evolution have produced beings capable of rational thought and moral action? The improbability suggests design. Moreover, they argue, the result is different in kind from physical evolution; consciousness, rationality, and morality are better explained by a "first cause" that itself possesses these features. The universe possesses a mathematical simplicity that evokes a religious (or quasi-religious) response from many scientists, and a beauty that for some is both awe-inspiring and sublime. The argument for God as the best explanation becomes more compelling when supplemented with personal religious experience of the divine or, in Immanuel Kant's phrase, of "the moral law within."

God and specific scientific results. In cosmology, the "singularity" of the Big Bang seemed to offer support for a doctrine of creation. In Jim Hartle and Stephen Hawking's quantum cosmology, however, there would be no $t = 0$ (time equals zero), hence no time at which God could create. Perhaps creation could be understood as the contingency of the world on God, even if there were never a "moment of creation," as Robert John Russell posits.

Neo-Darwinian evolution involves random genetic variation and selective retention by the environment. Denying evolution seems impossible, but theists have argued that the process may be "guided" by God in ways not yet fully visible or understood. Sociobiology and evolutionary psychology also challenge the ontological uniqueness of the human animal and hence challenge claims that humans are created "in the image of God."

The neurosciences can increasingly reconstruct the neural correlates of cognitive functions. Will they someday be able to detect the neurological footprints of God's interactions with individuals?

Might they discriminate between genuine and counterfeit experiences of God? Or will God's interactions with the world always escape human detection and rational analysis?

"God beyond God," experience, and mystery

The history of the interrelations between God and science mirror something of the history of God and philosophy. Like philosophy, science uses its analytic tools to falsify an ever larger number of specific claims about God. Yet neither can verify the divine, and neither can rule out God's existence. The experiences of something transcendent, someone divine, remain; hence room remains for conceiving God in a way that conflicts with neither science nor philosophy (the Transcendent Other, the "God beyond God"). New philosophical theologies, such as panentheism, can reformulate traditional claims about God's relationship with the world in new and more adequate ways. In the end, the question of God remains part of the ultimate mystery that faces humans in their walk between birth and death.

See also CREATIO EX NIHILO; DIVINE ACTION; EMERGENCE; GOD OF THE GAPS; MONOTHEISM; NATURAL THEOLOGY; OMNIPOTENCE; OMNIPRESENCE; OMNISCIENCE; PANENTHEISM; THEISM; THEOLOGY

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GÖDEL'S INCOMPLETENESS THEOREM

By the early part of the twentieth century, the work of mathematical logicians such as Gottlob Frege, Bertrand Russell, and Alfred North Whitehead had honed the axiomatic method into an almost machine-like technique of producing mathematical theorems from carefully stated first principles (axioms) by means of clear logical rules of inference. In 1931, however, Kurt Gödel (1906–1978), an Austrian logician, uncovered a surprising limitation inherent in any axiomatic system intended to produce theorems expressing the familiar mathematical properties of integer arithmetic.

Gödel developed a method, whose reach was slightly extended by J. Barkley Rosser in 1936, that shows how, given any such (consistent) system of axioms, one can produce a true proposition about integers that the axiomatic system itself cannot produce as a theorem. Gödel's incompleteness result follows: Unless the axioms of arithmetic are inconsistent (self-contradictory), not all arithmetical truths can be deduced in such machine-like fashion from any fixed set of axioms. This result, that here consistency implies "incompleteness," has striking implications not only for mathematical logic, but also for machine-learning (artificial intelligence) and epistemology, although its precise significance is still debated.

Gödel's work was stimulated by a program of the mathematician David Hilbert (1862–1943), whose goals included showing that the consistency of higher mathematics need not be based solely upon faith in the reasonableness of its axioms and methods, but could be established using means no more questionable than those of elementary arithmetic. The link Gödel discovered between consistency and completeness of elementary arithmetic, however, led him to a further result strongly suggesting that this goal, as originally envisioned by Hilbert, is unattainable. Although relatively few nonspecialists have mastered Gödel's proof, many general readers have attained an appreciation of his argument through popular accounts of its connection with familiar paradoxes involving self-reference.

See also ARTIFICIAL INTELLIGENCE; MATHEMATICS; PARADOX, SELF-REFERENCE

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W. M. PRIESTLEY

GOD, EXISTENCE OF

Most theists tend to think of God as the Supreme Being. Human knowledge and power are strictly limited, while God is omniscient and omnipotent. But humans are beings and God is a vastly superior being. Hence human beings exist and God exists in exactly the same sense. The tradition of Christian theology, however, also contains conceptions of the differences separating God and creatures that are more radical. According to Thomas Aquinas (c. 1225–1274), for example, there is in human beings a distinction between essence, which is to say what human beings are, and existence. But in God essence and existence are identical; God's essence is to exist. God is Being Itself, not one being among others. Thus humans exist and God exists in different though analogously related senses. And an even more radical separation is found in the mystical theology of Meister Eckhart (1260–1328). He distinguishes between God (*Gott*) and the Godhead (*Gottheit*). The Godhead is an aspect or dimension of divine reality that is above or beyond being. It is neither a being nor Being Itself. Paradoxically, it cannot be said to exist, even though it is the Ultimate Reality. Jean-Luc Marion develops a conception of this sort in his aptly titled *God Without Being* (1991).

Evidential support for claims about the existence of God comes from several sources. They include religious experience, revelation, and theological reflection. According to William P. Alston's *Perceiving God* (1991), claims about how God is interacting with a human subject of religious experience derive prima facie epistemic justification from a kind of nonsensory perception in which it seems to the subject that God is performing actions of various sorts. The God encountered in such experiences is taken to be a being capable of interacting with human beings. In the Hebrew Bible, when Moses asks God to make known the divine name, God says in response to Moses, "I am who I am" (Exod. 3:14). According to some interpretations, it is revealed by means of this response that God is Being Itself. The idea that God is not just a being among beings thus derives epistemic warrant from scriptural revelation. And in *The Courage to Be* (1952), Paul Tillich speaks of the God above the God of theism. He also claims that the divine Ultimate Reality is not a being or even Being Itself, but is instead the Ground of Being. Theological reflection therefore lends credibility to the claim that God is somehow beyond being.

However, one must turn to certain parts of natural theology if one wishes to find a source of evidence for the existence of God that is sensitive to empirical science. According to Immanuel Kant (1724–1804), natural theology's main arguments for God's existence may be classified as ontological, cosmological, or teleological. Anselm of Canterbury (c. 1033–1109) is the author of the first and most famous ontological argument. He attempted to derive the existence of God from the idea of God as a being greater than which cannot be conceived. But since the premises of ontological arguments are supposed to be knowable a priori and so independent of human experience of the world, such arguments do not in any way rely on scientific knowledge of that world.

Cosmological arguments do appeal to premises about the empirical world that is the object of scientific inquiry. Two familiar cosmological arguments are among Aquinas's celebrated five ways of proving the existence of God. One starts from the premise that there are now things undergoing change and things causing change; it concludes that an unchanging first cause of change exists. The other starts from the premise that there are contingent things that might not have existed; it concludes that there is a necessary being on which contingent things depend for their existence. Because the premises of these two arguments invoke only very general features of the world that humans experience, their truth does not depend on the details of the scientific worldview. There are, however, cosmological arguments that are sensitive to such details. In his contribution to *Theism, Atheism, and Big Bang Cosmology* (1993), William Lane Craig argues for God's existence from physical cosmology. According to Big Bang cosmology, the cosmos began to exist twelve to fifteen billion years ago. Reasoning from the principle that anything that begins to exist must be brought into existence by something, Craig concludes that God brought the cosmos into existence. Craig's argument is, of course, quite controversial. In his contribution to *Theism, Atheism, and Big Bang Cosmology,* Quentin Smith contends that Big Bang cosmology provides the basis for a successful argument to atheism.

But science bears most directly on natural theology through teleological or design arguments. The best known design argument is contained in William Paley's *Natural Theology* (1802). Paley argues for an analogy between the order displayed by biological structures, such as the human eye, and the order of mechanical devices, such as watches that are known to be products of design, and he concludes that God designed those biological structures. This sort of analogical design argument was subjected to devastating criticism by David Hume (1711–1776), and Darwinian mechanisms involving variation and natural selection have successfully explained a great deal of biological order. So Paley's design argument has lost its popularity.

More recent design arguments appeal to other sorts of natural order. In *The Existence of God* (1979), Richard Swinburne argues that the temporal order in the cosmos expressed by natural laws together with the fact that nature is composed of only a few elementary building blocks are evidence of design. He concludes that this evidence boosts the probability of God's existence. Others have drawn attention to the fact that various parameters such as certain physical constants and initial conditions of the cosmos at the Big Bang must lie within narrowly restricted limits if life is to evolve. They contend that God fine-tuned those parameters for the purpose of producing either life of some sort or other, or human life in particular. These arguments too have turned out to be controversial.

And in the United States, the Intelligent Design creationism movement aims to overthrow Darwinism. Michael Behe, one of the prominent figures in this movement, argues in *Darwin's Black Box* (1996) that molecular and cell biology have revealed irreducible biological complexity that cannot be explained in terms of Darwinian mechanisms of variation and natural selection. Behe's view is that such complexity is the product of divine design. Intelligent Design creationism has been vigorously disputed by many scientists and philosophers. A balanced and comprehensive presentation of the views on both sides of this new outbreak of warfare between science and religion may be found in *Intelligent Design Creationism and Its Critics* (2001), a volume edited by Robert T. Pennock. It remains an open question whether any part of scientific knowledge supports or undermines belief in the existence of God.

See also COSMOLOGICAL ARGUMENT; DESIGN; INTELLIGENT DESIGN; ONTOLOGICAL ARGUMENT; TELEOLOGICAL ARGUMENT

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PHILIP L. QUINN

GOD OF THE GAPS

The phrase *God of the gaps* refers to attempts to use statements about divine intervention in the physical world to fill in the "gaps" in scientific explanation. It is the attempt to introduce God as an explanatory hypothesis on the level of efficient causality to make up for limitations in current scientific understanding. The approach simply does not work because eventually scientific understanding closes the gap, making the appeal to divine explanation irrelevant. The approach is not taken seriously as a way of relating science and religion because it violates several fundamental principles of causal analysis and explanation in both science and theology.

History

The phrase *God of the gaps* is often credited to Charles A. Coulson in his book *Science and Christian Belief* (1955). This is certainly one of the first places where the phrase appears in material directly related to the science and religion discussion, but there are antecedents that appear years or even centuries earlier. In his *Letters and Papers from Prison,* German theologian Dietrich Bonhoeffer in correspondence from May 25, 1944, observes in response to Carl F. von Weizsacker's *The World-view of Physics* that:

> Weizsacker's book . . . brought home to me how wrong it is to use God as a stop-gap for the incompleteness of our knowledge. For the frontiers of knowledge are inevitably being pushed back further and further, which means that you only think of God as a stop-gap. He also is being pushed back further and further, and is in more or less continuous retreat. We should find God in what we do know, not in what we don't . . . (p. 190–191).

Bonhoeffer clearly saw the danger of placing God on the level of secondary causal explanation. God and the God hypothesis would be edged out, just as the astronomer Marquis de Laplace replied "I had no need of that hypothesis" when Napoleon asked why he did not discuss God in his writings. According to Ian Barbour in *Religion and Science: Historical and Contemporary Issues* (1997):

> The "God of the gaps" was as unnecessary in biology after Darwin as it had been in physics after Laplace. Adaptive changes could be accounted for by random variation and natural selection without involving divine intervention. We have Darwin to thank for finally making it clear that God is neither a secondary cause operating on the same level as natural forces nor a means for filling gaps in the scientific account. (p. 73)

The concept of God intervening from beyond to fill in inadequate knowledge or to resolve human problems actually goes back in Western culture to the ancient Greeks and the understanding of a *deus ex machina* (god of the machine) found in Greek theater. When a plot became too convoluted (or the audience's patience and endurance was wearing thin) an actor wearing the mask of the appropriate Greek deity would literally be lowered onto the stage from above by a crane (the machine) and resolve the plot conflicts, restore order, and serve out justice. In later thought, the phrase *deus ex machina* came to refer to any theological concept that involved God directing human or earthly events by dropping out of the supernatural into the natural. The *ad hoc* character of the concept expresses a form of theological desperation in which divine involvement cannot be understood in a coherent way with other forms of rational explanation.

Analysis

Since the time of Aristotle in Western culture a distinction has been made between primary and secondary causal analysis. Primary causal analysis (formal and final) has to do with the ends or purposes of any physical existent and secondary analysis with the means for its arisal (material and efficient). The great gains in scientific analysis have been accomplished at least in part by focusing on secondary analysis, which is observable, measurable, and repeatable. The power of scientific analysis lies precisely in the intentional limiting of the questions to the physically empirical and verifiable. Science as part of its methodology assumes that there will be material and efficient explanations of physical phenomena, that is, the methodology is inclusive of secondary causal analysis. This focus is at the heart of the scientific revolution of the seventeenth century. Theology and philosophy on the other hand have focused on the origins and ends of physical existence. To introduce God as a part of the secondary causal analysis violates principles of scientific understanding and commits a category mistake in causal analysis.

It must also be said that a constructive relationship between religion and science would involve connecting the two forms of causal analysis. Multiple strategies have been proposed for this with God working either "before" or "behind" the physical systems. The former was approached in

Enlightenment deism, where God arranged everything "before" the creation like a divine clockmaker and then left the created order to run on its own. This position, while popular in the eighteenth century, was later seen to deny the understanding of God involved in a continuing creation (*creatio continua*) and to be contradictory to the Abrahamic faith traditions.

Since about 1990 attention has been devoted to formulating theories where God works in and through the physical systems, such as in quantum indeterminacy, without violating known physical or biological laws. This "causal joint" discussion has resulted in a number of new theories of divine action ranging from *top-down* or *whole-part* causation (Arthur Peacocke) to *bottom-up* (Robert John Russell), *Persuasion* (John Cobb, David Griffin), *Information* (John Polkinghorne), or *Self-Limitation* (W. H. Vanstone), to name a few. What unites these diverse approaches is their commitment to respect the various physical and life sciences in their causal analyses and yet provide opportunities for dialogue on boundary questions, the ethical application of scientific technology, and other areas of common concern. Mutual respect between science and religion permits this in a way that a "God of the gaps" approach does not because it violates the integrity of both. For these reasons, among others, both "God of the gaps" and *deus ex machina* are not seen as viable concepts for theological understanding in relating science and religion.

See also ARISTOTLE; CAUSALITY, PRIMARY AND SECONDARY; CAUSATION; CREATIO CONTINUA; CREATIO EX NIHILO; CREATION; DEISM; DIVINE ACTION; GOD; GOD, EXISTENCE OF; SKYHOOKS

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ERNEST SIMMONS

GOULD, STEPHEN JAY

Stephen Jay Gould was born on September 10, 1941, in New York City. He was educated at Antioch College in Ohio and then trained as a paleontologist, doing his doctoral work at Columbia University in New York. His first academic position was at Harvard University in Cambridge, Massachusetts, where he remained for the rest of his life, later adding to his responsibilities a curatorship in paleontology at the American Museum of Natural History in New York. Gould received many honors, including numerous honorary doctoral degrees, and was a member of the National Academy of Sciences.

Gould's early scientific work focused on land snails in Bermuda, and at first he worked in a fairly conventional Darwinian fashion, seeing natural selection as the main cause of evolutionary change. But soon, he and paleontologist Niles Eldredge began trying to break the paradigm of conventional Darwinism, which sees the fossil record as essentially flowing from one form to another, with all gaps due to inadequacies in the record. Gould and Eldredge forwarded a theory of *punctuated equilibrium,* arguing that the fossil record shows stasis (no appreciable change, for periods of time, in some particular line of organisms), followed by very rapid change. The gaps in the record therefore reflect real gaps in the fossilization process.

Gould held to the theory of punctuated equilibrium throughout his life, although the causal mechanism for the process was often in flux and not entirely clear. For a while, Gould floated the idea of *saltations* (real macromutations that jump from one species to another), but this theory was criticized by population geneticists, causing Gould to look for other non-Darwinian, nonselective mechanisms. Together with molecular evolutionist Richard Lewontin, Gould argued that many aspects of organic nature are nonadaptive and could not have been produced by selection. Lewontin and

Gould argued that many features of plants and animals are like spandrels (the tops of columns in medieval churches); they are simply byproducts of the building process and thus without any great biological significance.

Much of Gould's work was not presented directly to his fellow professionals. He was a master at writing for a general audience, especially in essay form. For thirty years he wrote a monthly column called "This View of Life" in the magazine *Natural History.* In this column, Gould explored hundreds of different topics, not all of them related to biology. The essays were collected in several very successful volumes, beginning with *Ever Since Darwin* (1977). Gould also wrote books on general topics, including the history of brain science in *The Mismeasure of Man* (1981) and the fossils of the Burgess Shale in Canada in *Wonderful Life* (1989). At the scholarly level, Gould published numerous articles on the nature of the fossil record, usually in the journal *Paleobiology,* and the book *Ontogeny and Phylogeny* (1977) on the importance of development. Just before he died, Gould completed *The Structure of Evolutionary Theory* (2002), a comprehensive book covering all of his thoughts about evolution. In this last book, Gould turned to the history of science, as he had often done earlier, not merely to develop his ideas but to demonstrate that he was part of a respectable tradition, while his opponents were not.

Gould was admired by the general public, but many of his fellow evolutionists were less open in their praise, perhaps because of professional jealousy combined with discomfort at Gould's arrogant nature. Some critics felt that Gould's ideas were, scientifically speaking, somewhat shallow: Detailed examination did not always bear them out. By the time of Gould's death, consensus on the Eldredge-Gould claim about the nature of the fossil record was that it probably has merit, although there are many exceptions. The lack of a convincing causal hypothesis for punctuated equilibrium certainly counts against it. However, Gould's early stress on the importance of development for a full understanding of the evolutionary process seems fully borne out as molecular biologists turn their interests to questions of history.

Gould admitted that he always wrote with a concern for the morality beneath the surface of his science. A nonpracticing Jew with a Marxist background (the lasting influence of which was a matter of debate), he felt strongly about all matters of prejudice. In the 1970s, Gould was one of the leaders against sociobiology's attempts to explain human nature in terms of biology. Gould argued that sociobiology was not real science, but simply conservative ideology in fancy dress. For him, culture is essentially a spandrel, with no real biological importance. Undoubtedly the Lewontin-Gould attack on adaptation was motivated in part by this continued critique. Sociobiologists argued strongly that human nature is directly adaptive, such that men and women, for example, are psychologically as well as physically different because of their biology. Gould was determined to counter such views.

Gould also saw claims about biological progress as being part and parcel of the offensive ideology against which he fought, which set humans at the top of the animal hierarchy, with white gentiles at the top of the human chain. Gould saw Darwinism, with its emphasis on the success of the fittest, as badly bound up with claims about progress, and this was another reason to attack adaptationism. Many of Gould's popular works, especially *The Mismeasure of Man* and *Wonderful Life,* were explicit critiques on progressionism. Whether or not Gould was correct, such views brought him into conflict with many of his fellow evolutionists. British science writer Richard Dawkins, an ardent Darwinian and progressionist, took strong offence at Gould's thinking, which Dawkins felt distorted and belittled the opposition. In one of his essays, Gould accused the Jesuit paleontologist Pierre Teilhard de Chardin of being responsible for the Piltdown hoax. Many critics, particularly many Catholics, took umbrage at this accusation, since Gould's evidence was slim. Careful examination of the essay, however, shows that Gould's real intent may have been to read Teilhard out of science. As the twentieth century's most ardent progressionist, Teilhard had to be exposed as a man without moral or scientific authority.

Despite this attack on Teilhard, Gould's attitude toward religion was far more complex than that of a typical atheist. Although a nonbeliever, Gould had a passion for singing oratorio, which was equaled by his passion for baseball. He was, in a sense, a deeply religious man, despite the absence of any formal theology. He knew the Bible, both the Old and New Testaments, very well, and he frequently used biblical stories or allusions to illustrate points in his science writing. As an ardent evolutionist, Gould stood firmly against biblical literalists and creationists, and in 1981 he served as an expert witness for the American Civil Liberties Union in its successful litigation against a creationist law that had been passed in Arkansas. One of his last books, *Rocks of Ages* (1999), deals explicitly with issues of science and religion. Gould takes the position of the neo-orthodox (like Langdon Gilkey), arguing that science and religion are different dimensions for understanding and feeling—he calls them *magisteria*—and hence can not come into conflict if properly understood.

Unfortunately, Gould never really explored the ways in which conflict is avoided, and one is left with the impression that any compromise is going to favor religion. Gould's worldview would not allow miracles, for instance, and hence it would be necessary to interpret the resurrection symbolically or metaphorically. Such an approach may be acceptable to some Christians, but not to all, or indeed to most. In a way, therefore, Gould comes across as a logical positivist who is prepared to allow a role for religion as long as it is confined to sentiment, feeling, and morality, but makes no claims about matters of fact.

Gould died on May 20, 2002, in New York City. It is difficult to make long-term predictions about his lasting influence, although he will surely always be celebrated as a brilliant popular writer. It is less likely that he will be remembered as a significant scientist or as a major player in the debate about science and religion.

See also ADAPTATION; CREATIONISM; DARWIN, CHARLES; EVOLUTION, BIOLOGICAL; POSITIVISM, LOGICAL; SOCIOBIOLOGY; TEILHARD DE CHARDIN, PIERRE

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MICHAEL RUSE

GRADUALISM

Gradualism, also called *phyletic gradualism,* is the view that the course of evolution is gradual with small changes accumulating through time. Gradualism is opposed to *punctualism,* where evolutionary change is thought to happen in short episodes of rapid evolution followed by long periods of stasis when little or no evolutionary change occurs. The latter view is based on the interpretation of the fossil record and is common among palaeontologists, whereas the former view builds on a version of population genetics theory. However, most evolutionary biologists hold the view that the two concepts are not necessarily contradictory because gradual changes in genotype may occasionally lead to major changes in phenotype.

See also CATASTROPHISM; EVOLUTION; PUNCTUATED EQUILIBRIUM

VOLKER LOESCHCKE

GRAND UNIFIED THEORY

A Grand Unified Theory (GUT) unifies, or interrelates in a single quantum field interaction, the three fundamental nongravitational forces: electromagnetism, the weak nuclear interaction, and the strong nuclear interaction. These three forces are each characterized by a *coupling constant,* which gives the strength of the interaction by a range over which the force acts (long-range like electromagnetism, or short-range like the two nuclear forces), and by certain characteristic symmetries that are described by mathematical symmetry groups. A successful GUT would show how the three different coupling constants become identical at some very high energy, subsume the symmetries of the three individual interactions in a much larger symmetry group, and explain all of the masses, processes, couplings, decays, ranges, and other behaviors of all particles at lower energies—lower than the GUT unification energy. The current standard model of particle physics, though highly successful in other ways, does not do this. Further, there are strong indications that a more complete and adequate explanation, describing deep connections that have so far evaded our understanding, awaits a successful GUT model.

A GUT would express the fact that at the most fundamental level all nongravitational interactions, and all particles, quarks, electrons, and neutrinos, are intimately interrelated and, in fact, identical above the unification energy. Their difference at low energies is expressed in a GUT by saying that the symmetries characterizing the interactions at very high energies, rendering particles and forces identical or equivalent, are "spontaneously broken" below the unification energy. Such spontaneously broken symmetries are present in the underlying relationships characterizing the system, but are not expressed—are hidden—in a given equilibrium state of the system, such as that realized in the present state of the universe. Construction of a GUT theory is an essential step towards achieving total unification, which would also include gravity. Although promising and detailed progress has been made on a number of fronts, there was no adequate GUT as of 2002.

There are strong indications that all the basic physical interactions are intimately related and that they can be unified. In the mid nineteenth century, the Scottish physicist James Clerk Maxwell began realizing this intuition by unifying electrical and magnetic phenomena in his electromagnetic theory. In the 1970s, Sheldon Glashow, Stephen Weinberg, and Abdus Salam succeeded in developing an adequate electroweak theory, which describes how electromagnetism and the weak nuclear interaction are related, and how they are identical at temperatures above 10^{15} K (kelvin). This electroweak theory was confirmed in 1983 by the discovery of the W and Z massive bosons, which carry the electroweak force and which were predicted by the theory. A completely successful GUT would incorporate the strong nuclear interaction with this electroweak interaction in an analogous way at some higher temperature above 10^{27} K.

Part of the motivation for a GUT is the lack of explanation for many of the parameters and characteristics of the standard model, and of the universe itself. For example, there is no explanation for the baryon-anti-baryon asymmetry, which means that there is more matter in the universe than there is antimatter. There is also some positive experimental support for a GUT, including equality of the magnitude of the charges of the proton and the electron and the non-zero rest-mass of the neutrino. Furthermore, GUT candidates generically predict the decay of protons at some very slow rate, as well as the presence of monopoles and other topological defects, which are localized regions in which the vacuum energy is different from the rest of the universe (false vacuum). Observational limits on these phenomena are being used, and will continue to be used, to identify the most adequate GUT candidates.

From a cosmological point of view, the success of a GUT would mean that at some very early stage in the history of the universe—well before one second after the Big Bang, when the temperature of the universe was greater than 10^{27} K—the physics of the universe was characterized by just two interactions: gravity and the GUT interaction. The universe would have been much too hot for protons, neutrons, and electrons to exist, as they do at lower temperatures. As the universe expanded, it cooled. And, as it cooled below 10^{27} K, the GUT interaction split into the strong nuclear and the electroweak interactions. A short time later—still much less than one second after the Big Bang—when the temperature had plummeted below 10^{15} K, the electroweak interaction split further into the weak nuclear and the electromagnetic interactions. From that point on, the basic physics of the universe was the same as it is today, but devoid of the complex macroscopic and microscopic structures that developed much later.

Implications for theology

There are no direct implications of GUT unification for religion and theology, but there are several important indirect influences. First, GUT unification, when it is finally achieved, will contribute to describing how everything in material reality is intimately interconnected in very basic ways. Those relationships constitute reality as it is and are an essential part of how God's continuing creative action is realized—through these "laws of nature." Second, a GUT characterizes a definite, very early stage in the evolution of the universe. A successful GUT will strengthen the already strong case for the evolution of the presently lumpy, cool, complex, and highly differentiated cosmos from a very hot, simple, homogeneous, and relatively undifferentiated primordial state, which was characterized by a much simpler physics. For the theistic thinker, a GUT represents one of the key ways in which God gradually brought into being the reality of which human beings are a part.

See also FIELD THEORIES

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GRAVITATION

Gravitation is a universal attractive force exerted by any two physical bodies on each other, even though they may be separated by a large distance. Gravitation is responsible for making objects fall to the surface of the Earth (gravitational attraction of the object by the Earth), for the nearly circular motions of the planets around the sun (gravitational attraction of the planets by the sun), for the structure of stars and planets (gravitational attraction balanced by pressure forces of constituent particles towards each other), and for the structure of star clusters and galaxies (hundreds of millions of stars would fly apart from each other if not held together by gravity). Gravitation also controls the rate at which the universe expands, and is responsible for the growth of small inhomogeneities in the expanding universe into galaxies and clusters of galaxies.

Gravity is the weakest of the four fundamental forces known to physics, but it dominates on large scales because it is a long-distance force that is locally always attractive (in contrast to the far stronger electromagnetic force, which can both attract and repel, and cancels itself out on large scales). Thus gravitation is a dominant force in every day life, as well as in the motions of stars and planets and in the evolution of the cosmos. Indeed, it is one of the forces that makes our existence possible by enabling the formation and stability of plants like Earth that are hospitable to life. Without gravity (at approximately the strength it has on Earth) evolution of life would be difficult if not impossible. This fact can naturally lead to speculation that the existence and specific nature of gravitation could be part of a grand design allowing self-assembling structures to come into existence and lead to intelligent life. In this way, gravity can have theological significance.

Classical physics

Italian astronomer Galileo Galilei (1564–1642) first recognized in the early seventeenth century that when air resistance can be neglected, objects accelerate at the same rate towards the surface of the earth, irrespective of their physical composition. Thus a feather and a cannon ball will arrive at the same time at the earth's surface if simultaneously released from rest at the same height in a vacuum chamber. This means there is a universal rate of acceleration downwards caused by the earth's gravitational field—approximately 32 feet per second squared—irrespective of the nature of the object considered. Gravitational potential energy can be converted to kinetic energy, with total energy conserved, as for example in a roller coaster or a pole vaulter. This enables gravity to do useful work, as in a clock driven by weights or a water mill, but it also means people must work to go uphill. Gravity can also be a danger to people, who can fall or be hurt by falling objects. Despite this danger, gravity is an essential part of the stability of every day life—it is the reason that objects stay firmly rooted on the ground rather than floating into the air.

In the late seventeenth century, Isaac Newton (1642–1727) showed that the gravitational attraction of objects towards the earth and the motion of the planets around the sun could be described accurately by assuming a universal attractive force between any two bodies, proportional to each of their masses and to the inverse of the square of the distance between them. The attractive nature of gravity results because masses are always positive. On this basis he was able to explain both the universal acceleration towards the surface of the earth observed by Galileo and the laws of motion of planets around the sun that had been observationally established earlier in the century by Johannes Kepler (1571–1630). This was the first major unification of explanation attained in theoretical physics, showing that two phenomena that initially appeared completely unrelated had a unified origin. Newton's account of gravitation also explained why the direction of gravity varies at different places on the surface of the earth (always being directed towards its center), allowing "up" to be different directions at different places on the earth's surface (Australia and England, for example).

In conformity with the rest of theoretical physics, Newton's theory of gravity can be reformulated as a variational principle (Hamilton's principle or Lagrange's equations) based on minimisation of particular combinations of kinetic energy and gravitational potential energy along the trajectory followed by a particle. Gravity by itself is a conservative theory (energy is conserved), so there is no friction associated with the motion of stars and planets in the sky, and their motion is fully reversible; the past and future directions of time are indistinguishable, as far as gravity is concerned. Newton was puzzled as to how the force of gravity, as described by his equations, could succeed in acting at a distance when there was no apparent contact between the bodied concerned. Pierre Laplace (1749-1827), a French physicist and mathematician, essentially resolved this puzzle by introducing the idea of a gravitational force field that fills the empty space between massive bodies and mediates the gravitational force between them. The concept of such fields became one of the major features of classical physics, particularly in the case of electromagnetism. In quantum theory the idea gravitational fields is revised and understood as a force mediated by the interchange of force-carrying particles.

Einstein and after

In the early twentieth century, Albert Einstein (1879–1955) radically reshaped the understanding of gravity through his proposal of the general theory of relativity, based on the idea that space-time is curved, with the space-time curvature determined by the matter in it. This theory predicts the motion of planets round the sun more accurately than Newtonian theory can, and also predicts radically new phenomena, in particular, black holes and gravitational radiation. Insofar as science has been able to test these predictions, they are correct. A problem with the theory is that it predicts that under many conditions (for example, at the start of the universe and at the end of gravitational collapse to form a black hole), space-time singularities will occur. Scientists still do not properly understand this phenomenon, but presumably it means that they will have to take the effect of quantum theory on gravity into account. General Relativity does not do so; it is a purely classical theory.

Quantum gravity theories try to develop a theory of gravity that generalizes Einstein's theory and is also compatible with quantum theory. Even the way to start such a project is unclear. Approaches include twistor theory, lattice theories, noncommutative geometries, loop variable theories, and superstring theories. None has reached a satisfactorily developed state, however, much less been tested and shown to be correct. Indeed, in many ways such theories are likely to be untestable. The most ambitious are the superstring theories, now extended into a metatheory of uncertain nature known as *M-theory,* which promises to provide a unified theory of all fundamental forces and particles. M-theory still has far to go before making good on that promise.

Despite the lack of a definite quantum theory of gravity, various attempts have been made to develop quantum theories of cosmology. These theories also face considerable conceptual and calculational problems. The satisfactory unification of quantum theory and general relativity theory, perhaps in some unified theory of all the fundamental forces, remains one of the most significant outstanding problems of theoretical physics.

The desire to develop a practical antigravity machine remains one of humanity's outstanding wishes. No present theory offers a way to such a machine, but the negative gravitational effect of the vacuum energy will continue to inspire some to hope that one day such a machine might exist.

See also BLACK HOLES; COSMOLOGY, PHYSICAL ASPECTS; FORCES OF NATURE; GALILEO GALILEI; NEWTON, ISAAC; PHYSICS, QUANTUM; QUANTUM THEORY; RELATIVITY, GENERAL THEORY OF; SINGULARITY; STRING THEORY; SUPERSTRINGS

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GEORGE F. R. ELLIS

GREENHOUSE EFFECT

In the Earth's atmosphere, there are five important greenhouse gases that occur naturally: carbon dioxide, methane, ozone, halocarbons, and nitrous oxide. In correct proportion, these greenhouse gases provide important protection for the Earth's surface. However, if the greenhouse gases become too concentrated in the Earth's atmosphere, then they create a greenhouse effect that overheats the Earth. Although a few scientists continue to dissent, there is near unanimity among climatologists that current global warming is caused by the dramatic increase in atmospheric carbon dioxide since the advent of the Industrial Revolution and the extraordinary increase in the combustion of fossil fuels. In her essay, "The Greening of Science, Theology, and Ethics," Audrey Chapman has argued that ecological ethicists must understand the science behind concepts such as the greenhouse effect in order to contribute meaningful ethical analysis.

See also ECOLOGY; ECOLOGY, ETHICS OF; ECOLOGY, RELIGIOUS AND PHILOSOPHICAL ASPECTS; ECOLOGY, SCIENCE OF

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RICHARD O. RANDOLPH

H

HEALING

See SPIRITUALITY AND FAITH HEALING; SPIRITUALITY AND HEALTH

HEISENBERG'S UNCERTAINTY PRINCIPLE

In 1927 the German physicist Werner Heisenberg (1901–1976) showed that quantum mechanics leads to the conclusion that certain pairs of quantities can never be measured simultaneously with arbitrarily high precision, even with perfect measuring instruments. For example, it is not possible to measure the position and the momentum of a particle with unlimited precision. If one denotes the uncertainty in the measurement of its position by $\Delta\ x$ and the uncertainty in its momentum by $\Delta\ p$ then Heisenberg's Uncertainty Principle states that the axioms of quantum mechanics require that

$$\Delta \times \Delta\, p \geq h/4\pi$$

where h is Planck's constant
($h = 6.626\ 068\ 76 \times 10^{-34}\ Js$).

The Uncertainty Principle is often presented as a manifestation of the fact that the act of measurement inevitably perturbs the state that is being measured. Thus, the smaller the particle being observed, the shorter the wavelength of light needed to observe it, and hence the larger the energy of this light and the larger the perturbation it administers to the particle in the process of measurement. This interpretation, while helpful for visualization, has its limitations. It implies that the particle being observed does have a precise position and a precise momentum which we are unable to ascertain because of the clumsiness of the measurement process. However, more correctly, we should view the Uncertainty Principle as telling us that the concepts of position and momentum cannot coexist without some ambiguity. There is no precise state of momentum and position independent of the act of measurement, as naïve realist philosophers had assumed. In large, everyday situations this quantum mechanical uncertainty is insignificant for all practical purposes. In the subatomic world it is routinely confirmed by experiment and plays a fundamental role in the stability of matter. Note that if we take the limit in which the quantum aspect of the world is neglected (so Planck's constant, h, is set to zero), then the Heisenberg Uncertainty would disappear and we would expect to be able to measure the position and momentum of any object with perfect precision using perfect instruments (of course in practice this is never possible).

The Uncertainty Principle has had a major effect upon the philosophy of science and belief in determinism. It means that it is impossible to determine the present state of the world (or any small part of it) with perfect precision. Even though we may be in possession of the mathematical laws that predict the future from the present with complete accuracy we would not be able to use them to predict the future. The Uncertainty Principle introduces an irreducible indeterminacy, or graininess, in the state of the world below a particular level of observational scrutiny. It is believed that this inevitable level of graininess in the state of matter in the universe during the first moments of its history led to the production of irregularities that eventually evolved into galaxies. Experiments are underway in space to test the detailed predictions about the variations left over in the temperature of the universe that such a theory makes.

Of the other pairs of physical quantities that Heisenberg showed cannot be measured simultaneously with arbitrarily high precision, the most frequently discussed pair is energy and time. Strictly, this pair is not a true indeterminate pair like position and momentum because time is not an observable in the way that energy, position, and momentum are in quantum mechanics. By using a time defined externally to the system being observed (rather than intrinsically by it), it would be possible to beat the requirement that the product of the uncertainty in energy times the uncertainty in time be always greater than Planck's constant divided by 4 π.

The physicist Niels Bohr (1885–1962) called quantities, like position and momentum, whose simultaneous measurement accuracy was limited by an uncertainty principle *complementary pairs.* The limitation on simultaneous knowledge of their values is called *complementarity.* Bohr believed that the principle of complementarity had far wider applicability than as a rigorous deduction in quantum mechanics. This approach has also been adopted in some contemporary religious apologetics, notably by Donald Mackay and Charles Coulson. There has also been an interest in using quantum uncertainty, and the breakdown of rigid determinism that it ensures, to defend the concept of free will and to provide a channel for divine action in the world in the face of unbreakable laws of nature.

The Uncertainty Principle also changes our conception of the vacuum. Quantum uncertainty does not allow us to say that a volume of space is empty or contains nothing. Such a statement has no operational meaning. The quantum vacuum is therefore defined differently, as the lowest energy state available to the system locally. This may not characterize the vacuum uniquely and usually a physical system will have more than one possible vacuum state. Under external changes it may be possible to change from one to another. It is therefore important to distinguish between the nonscientific term "nothing" and the quantum mechanical conception of "nothing" when discussing creation out of nothing in modern cosmology.

See also CREATIO EX NIHILO; DETERMINISM; DIVINE ACTION; FREEDOM; INDETERMINISM; PARADOX; PHYSICS, QUANTUM; DOWNWARD CAUSATION

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JOHN D. BARROW

HERMENEUTICS IN SCIENCE AND RELIGION

Hermeneutics is the branch of philosophy that deals with theory of interpretation. It can be argued that any discussion of the relationship between science and religion is implicitly or explicitly a matter of interpretation. This can be seen, for instance, in Ian Barbour's (1923–) advocacy of "critical realism" in matters both religious and scientific. Interpretation theory necessarily stands at the intersection of the dialogue between science and religion, though few authors in the field have articulated formal theories of interpretation as part of this exploration.

The etymology of the word *hermeneutics* begins with the ancient Greek god, Hermes, who was a messenger between the gods of Olympus, the gods of the underworld, and the mortal humans. Hermeneutics could literally be translated as the "science of Hermes." Called Mercury in the Roman tradition, Hermes was unique in the ancient pantheon as the singular interpreter between worlds, but one should not forget that he was also something of a trickster. The apparently simple task of interpretation turns out to be remarkably complicated and can make fools of everyone.

Hermeneutics first arises in the disciplines of interpreting sacred texts, historical events, and legal codes, but philosophers increasingly see its application to theories of understanding in the broadest sense. The book, poem, event, or law to be interpreted is referred to generically as the "text." The interpretation of texts is seen as a metaphor for all kinds of nontextual interpretative problems, for instance in social and psychological theories and increasingly also in the biophysical sciences.

Hermeneutics in science

Scientists tend to have a formalist approach to their disciplines, believing that science is a singular methodology leading to objective, realist accounts of phenomena. While this is often pragmatically justified in the narrow domains of particular sciences, philosophical reflection on the practice of science in the last century points to a much more nuanced and complicated view. The positivist view of science advocated by Moritz Schlick (1882-1936), Karl Popper (1902–1994), and others has largely fallen to a more contextual and constructivist understanding of science. Willard V. O. Quine (1908–2000), Arthur Fine (1937–), Hillary Putnam (1926-), and Thomas Kuhn (1922–1996) have argued persuasively that science is not a singular methodology, but a complex of diverse disciplines situated within particular historical and social contexts. The philosophical task now becomes explaining the progressive and efficacious results of scientific investigations and insights in spite of this situatedness.

A few examples will suffice to show how science engages in interpretation. In contemporary cosmology, the problems of quantum entanglement and the apparent "fine-tuning" of perhaps a dozen cosmological parameters leads to the extravagant and often nonempirical speculations of string theory, multiverse theory, and numerous accounts of the significance of quantum weirdness. In the case of multiverse theory, it remains to be seen whether these speculations will ever be more enlightening than debates about how many angels can fit on the head of a pin.

In molecular biology, the genome is increasingly referred to as a text or code, which is then interpreted in particular organisms to varying degrees, sometimes with a great deal of stochastic latitude, for instance as seen in the probabilistic occurrences of many genetically based diseases. Biology turns out to be all nature and all nurture, and the two cannot easily be separated in spite of reductionistic predilections.

Because of the historical nature of evolutionary biology, scholars continue to debate whether evolution has teleological biases or structures. Because researchers can only simulate evolution and cannot subject theories of evolution to laboratory-like replication and verification, they are not likely to ever resolve these questions. These arguments will always take on the status of interpretations in which empirical facts and logical arguments are mustered to support competing views to varying degrees of satisfaction.

Primatologists regularly draw analogies between humans and their primate relatives in order to decode the biological nature of human sexuality, sociability, and aggression. When primatologists compare baboons, gorillas, chimpanzees, or bonobos, let alone apparent cultural differences between groups within one of these species, it would be hard to know what is biologically normative for humans. These primate analogies to humans could be seen as an example of what philosophers denounce as the *naturalistic fallacy,* in which humans justify or deduce an "ought" of culture from an "is" of nature. The human species, however, exhibits a ubiquitous and perennial tendency, if not necessity, to extrapolate and analogize between the "is" and the "ought" as we develop our sense of individual selves and culture identity. The question is not *whether* to commit the naturalistic fallacy, but *how.* Again this is a matter of interpretation.

Hermeneutics in religion

Religions have long dealt with the problem of interpretation. When confronted with an archaic or foreign language in a sacred text, simple translation itself becomes an interpretative task. Sacred texts and traditions are full of other interpretative problems. Even if readers begin with the presupposition that the text is divinely revealed and in some sense perfect, as for instance with the status of the Koran for most Muslims, they must still confront their own finitude as the readers of such revealed texts. Ambiguity and conflict within the Koran necessarily give rise to a body of interpretation and case law that places this foundational religious text within a tradition of jurisprudence. Talmudic interpretations of Torah in Judaism are another explicit example of a hermeneutical process at work in religion.

Augustine of Hippo (354–430) and others in the early and medieval Christian movement argued that the Bible was often allegorical and not to be understood as literal. The parables of Jesus are explicitly metaphorical and thus also in need of interpretation. With the Protestant Reformation, Martin Luther (1483–1546), John Calvin (1509–1564), and others tended to reject allegorical interpretation as mere manipulation of the text for the political purposes of the Catholic hierarchy. A literal and univocal hermeneutics was advanced in which the Bible was open to the self-interpretation of every competent reader, even as it was widely translated in vernacular languages for the first time. Curiously, the Christian reform movement, which advanced this literal and univocal Biblical hermeneutics, quickly splintered into competing Protestant denominations. Radical Protestants argued that Biblical interpretation must be guided by the Holy Spirit, the same Spirit in which the text was written, or it could never be properly understood. As the New Testament itself warns us, even the devil quotes scripture.

Hermeneutics in philosophy

Hermeneutics rose as a formal philosophical discipline in the modern period. While one should be mindful of the rich histories and reflections on hermeneutics in other civilizations and traditions, the context in which modern European philosophers began to articulate formal theories of hermeneutics arises out of the life and death battles of the Reformation.

Friedrich Schleiermacher (1768–1834) and Wilhelm Dilthey (1833–1911) are widely credited with the rise of modern hermeneutics. Schleiermacher, for instance, united problems in biblical interpretation with the interpretation of other genres of literature, history, law, and philosophy. Schleiermacher articulated the problem of a hermeneutical circle in which the reading of a particular passage could only be understood in the context of the whole text and the reading of the whole text could only be understood in light of the interpretation of particular passages. Thus the correct reading of a text also needed to draw on other sources, including an understanding of the author's life and intentions. The goal was to "understand an author better than he understood himself." This also required an understanding of the entire cultural context in which the author's work emerged. At every level, the problem of a part and whole circularity arose for Schleiermacher, but he had a kind of sanguine optimism about the endeavor of achieving an objective reading of a text. One also sees in Schleiermacher's approach an affinity with early psychology and the other human sciences.

Others argue that authors do not actually understand themselves and that it is the job of the interpreter to decode the hidden meanings of the author's text. For instance, the self-understanding of the author or the surface reading of a text are covers for "false consciousness" of economic interests (Karl Marx) or the "unconscious projections" of psychological forces (Sigmund Freud). This critical turn toward a hermeneutics of suspicion, however, soon implicated the "objective" interpreter himself, since all interpreters and interpretations are ideologically biased. The reader is thus drawn into the hermeneutical circle as part of problem. A reader necessarily approaches the reading of a significant text with all kinds of assumptions; prejudices can simply predetermine the interpretation. The challenge of interpretation begins to look like a vicious circle in which readers project any and all prejudices onto the text.

Hans-Georg Gadamer (1900–2002) articulated a theory of interpretation that took the reader's situatedness fully into account. Interpretation was an encounter between the two worlds of the author and the reader. The text became an independent entity with a life of its own. Good interpretation sought for a "fusion of horizons" between the reader, the author, and the life of the text. The task was to reflect critically about the prejudgments brought to the table by the reader, seek a provisional critical distance from these prejudices, and be open to encountering some new understanding through a new reading, which might then inform a new set of assumptions for future readings. The goal was to turn what was understood to be a solipsistic hermeneutical circle into an open-ended and progressive hermeneutical spiral.

Postmodern hermeneutics

The hermeneutics of suspicion and the self-implication of the reader in the hermeneutical dynamic, however, also gave rise to the more extreme formulations of radical deconstruction and postmodern hermeneutics. Michel Foucault (1926-1984), Jacques Derrida (1930–), Richard Rorty (1931–), and others have argued for the impossibility of interpretative truth claims. Because one cannot escape prejudice, delusion, and interested rationalization in every interpretative move, the best one can do is not delude oneself through an endless process of deconstruction (the double meaning is intentional). The challenge of postmodernism is to live in the flux of change without the crutch of artificially willed certainty.

Scientism has come to be seen by many in the humanities as just such an oppressive metanarrative. There has been a major movement to apply social-critical theory to the understanding of scientific knowledge as socially constructed. Historians and social critics enter the scientific discourse like anthropologists in a foreign land. They read the ethnography of the laboratory, the economics of the pharmaceutical research, the history of physics, and the metaphoric symbolism of genetic engineering in order to uncover hidden meanings that are not self-apparent to members of the "tribe." These studies often offer some enlightening insights into how the actual practice of science differs from the philosophy of science or the self-understanding of scientists, but the hermeneutical circle also puts into question the ethnography, economics, psychology, and symbolism of the new cultural critics of science.

Contemporary hermeneutic theory tends toward philosophical and ethical pragmatism. The truth of a theory or interpretation is understood not through some direct correspondence to reality but through the practical consequences of its applications. In this sense, postmodernism can be seen as having deep affinities with some religious and scientific philosophies. The reluctance of physicists to draw metaphysical implications from quantum mechanics can be seen as a kind of pragmatism. Plato (428–347 B.C.E.) offers the notion of a Noble Lie necessary for well-being of the Polis and the individual. Jesus' warning to judge the false prophets on the consequences of their ministry, to be wary of rotten "fruit" in "sheep's clothing," can also be seen as a pragmatist apologetic. Buddhism includes the notion of *Upaya,* effective teachings that are not necessarily true but that work nonetheless. Even if foundational theories of knowledge are unattainable, one might still find in lived experience some practical guidance.

That science is a socially and historically constructed form of knowledge is in retrospect an obvious truism. That science is merely a socially constructed form of knowledge without reference to a "real" reality is a highly problematic assertion. The problem is compounded by the either/or, subjective/objective, rational/irrational dichotomies upon which the modernist worldview is founded. Here, too, an understanding of postmodernism is helpful to the science and religion interdisciplinary dialogue.

Religion, which has long been attacked and deconstructed as mythic delusion, can now claim some pragmatic parity with the scientific worldview that attacked it within this pragmatist hermeneutic. History, anthropology, psychology, sociology, gender studies, and literary theory have long been conversation partners in serious religious thought and inquiry, but they are now new dialogue partners for the biophysical sciences.

Once perceived as hostile to a committed life of faith, modernist critical theory has turned into a postmodernist helpmate for religion in nurturing deep and intellectually vibrant religious belief. The fact that there are invisible social and psychological processes that corrupt and distort one's understanding of the divine (or nature) and that unconscious processes can be exposed and demystified through critical interpretative theory is an occasion to reaffirm human finitude and humbleness before the divine and the larger nature that contains human "be(ing) longingness." After all, in most faith traditions such humility is prescribed. The Judaic prohibition against idolatry, the *via negativa* of medieval Christianity, the *Neti Neti* of Hinduism, the *Sunyata* of Buddhism, and the Islamic sense of divine transcendence are all rich affirmations of human epistemological finitude before the Ultimate.

Many in the biophysical sciences, however, tend to feel threatened by these social constructionist studies. Most scientists believe that their theories, models, and measurements are in some sense directly related to reality and not simply an elaborate projection of social prejudice and power. The strong social constructionist argument would render the predictive and explanatory power of science as nonsensically coincidental. Airplanes really fly; cell phones really work. Science produces untold efficacious results in daily life. And while belief in antibiotics or acupuncture will improve the effect of the remedy, they will also work independently of belief system. The truths of science, like the truths of religion, must surely lie somewhere between relativistic social constructionism and naive realism, though scholars are struggling to find a new philosophical language to account for this in-between knowing.

Hermeneutics in linguistics

These hermeneutical conundrums are also characterized by a linguistic movement in philosophy of science and philosophy in general. Ludwig Wittgenstein (1889–1951), for instance, came to reject his own earlier positivist theory of language and science. Wittgenstein recognized that all languages, from mathematical formalism to one's mother tongue, are internally self-referential (Kurt Gödel (1906-1978) proved the even mathematical languages are self-referential). Language is understood as a kind of game playing, in which the rules are arbitrary to each particular user-group. One can talk about language games within the boundaries of rational, irrational, and other rational. Within the rules of their respective language games, an Orthodox Jew can be every bit as rational as a particle physicist; indeed, they can be one and the same person. There is, however, no master language or logic of truth, contrary to the hopes of the scientific positivists and religious fundamentalists.

Paul Ricoeur (1913–) carefully considers this new linguistic analysis and argues that far from being merely arbitrary, human language builds upon a deep symbolic structure of the universe itself. It is not just that human language reflects a semiotic/semantic structure internally; the universe itself is constituted through semiotic/semantic processes. Ricoeur advocates metaphoric realism. Words achieve their denotative function only through connotative associations in established usage. Because the function of language is first established in connotation, the result is a theory of metaphors as linguistically primordial. Ricoeur avoids descending into relativistic nonsense by grounding human language in a semiotic and semantically rich universe.

Many religions consider language to be somehow primordial to the material constitution of the universe. In Hinduism, the Upanishads talk of a primal word, *Om,* which functions as the creative source of all nature. The Greeks, including Plato, drew upon Heraclitus' notion of *Logos,* viewing the embodied word as that fire that animated and ruled the world. In Jewish Midrash, the grammatical ambiguity of the first line of Genesis, leads to philosophical speculation about a pre-existent *Torah,* which God uses to speak reality into being. In Medieval Judaism, this rabbinic tradition gave rise to the wild speculations and philosophical subtleties of the Kabbalists. In the Gospel of John, Christians celebrate this Word or Logos in a radical incarnationalist vision of a cosmic Christ by whom and through whom all things are made and from whom everything that was created received life.

So, too, throughout the sciences theoretical and research projects point beyond mere materialism and reductionism to a new kind of ontological entity called "information." Contemporary scientists take matter-energy and space-time as metaphysical foundations, but increasingly need to include some concept of "information" in their metaphysics, even though information is somehow immaterial, ephemeral, and context dependent.

The relativistic tendencies of postmodern hermeneutics and culture at large now present a great challenge at a time in human history that also requires intellectual rigor and committed moral action in the face of theoretical and existential uncertainty. The hermeneutical dynamic may be unavoidable, but it need not be a self-confirming or paralyzing circle of prejudice. While unavoidable, the cultural biases of the interpreter are not necessarily bad, for a tradition is paradoxically the sustaining foundation upon which deconstructive hermeneutics builds new meanings. All deconstructions are parasitic on some functional metanarrative. Nor does interpretation always necessarily confirm the prejudgments of interpretation. The text presents a limited matrix of possible and plausible interpretations. The trick will be not to deny one's hermeneutical finitude through some fundamentalist dogmatism or callous rhetorical will-to-power, but to honor the hermeneutical process and open the solipsistic circle into an evolving spiral. New and different voices in one's social and biophysical ponderings can help provide powerful insights, even as the text or phenomenon have the capacity sometimes to direct one to new insights in spite of oneself.

Human reason, like the universe, is polyglot. But interdisciplinary, cross-cultural, and intra-phenomenological translation projects are possible and necessary. With a combination of interpretative insights of science and religion, like the blind men describing the elephant in the Jainist-Buddhist myth, a "fusion of horizons" and a fuller understanding of science, society, self, and the sacred might be gained. A rigorous and open-ended conversation of tolerance and humility is an ethical and epistemological prescription for both science and religion as we confront the extraordinary challenges of our time and the stunning complexities of the universe and ourselves.

See also SCRIPTURAL INTERPRETATION

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HIERARCHY

The word *hierarchy* stems from the Greek word *hierarches,* and early usage referred primarily to ecclesiastical structure and authority. The term is now widely used in a number of fields and generally denotes an inter-level relationship, usually conceived as a vertical layering of levels that implies higher value, power, or centralization at the top, and less of these qualities at the bottom.

History of the concept

The ancient Greek philosopher Plato has had an enormous influence on hierarchical thinking. In works such as the *Republic* and *Phaedo,* Plato argued that the world is divided into a lower, chaotic material reality, and a higher reality of forms that is the genuine source of truth, beauty, and the good. For Plato, this ontological distinction was necessarily related to epistemological and moral ones, for the realm of the forms are the source of true knowledge as well as being the ultimate good that all seek. Human beings were seen as a composite of the two worlds, the irrational world of matter and the rational world of the forms. In Plato's framework, the good person is one who shuns material things and pursues rational inquiry in accordance with one's true, nonmaterial nature.

During the Roman era, Plotinus (205–270) and other neo-Platonists expanded Plato's dualism into what twentieth-century philosopher Arthur Lovejoy (1873–1962) called the great chain of being. According to this view, God is the most real, out of which all other things emanate. Material reality is that which is most distant from the plenitude of God and, in a sense, the least real. As a composite of the different levels of reality, human beings stand at a halfway point, both material and spiritual. Neo-Platonism profoundly influenced the development of Christian theology, particularly through the writings of Augustine of Hippo (354–430), Pseudo-Dionysus (c. fifth century C.E.), and Bonaventure (1217–1274). In a Christian framework, angels naturally fit into a neo-Platonic framework as beings who occupied a higher level of reality. For Augustine in particular, evil could be explained as the absence of good, an irrational move from the most real (God) towards the unreal.

The rise of modern science played a significant role in the demise of hierarchical understandings of the world. Early scientific thinkers were influenced by philosophers such as William of Ockham (c. 1285–c. 1347), who denied Plato's theory of forms and hierarchical ontologies. This and other factors led to an understanding of the physical world that emphasized material causes alone, a tendency that seemed vindicated by the work of Galileo Galilei (1564–1642) and Isaac Newton (1642–1727). Such materialistic views were typically reductionistic in character. Materialist reductionists inverted and then rejected the neo-Platonic hierarchy of being, claiming not only that it is the material world that is most real, it is the only reality. Such materialism not only influenced scientists such as Pierre-Simon Laplace (1749–1827), but also the whole trajectory of nineteenth-century philosophy.

In the twentieth century, the legitimacy of ontological and moral hierarchies was intensely debated within specific fields of philosophy and theology. Debates about ontological hierarchies focused on questions of reductionism and emergence or holism, much of which centered on the status of the mind and human person. Reductionists emphasize that the material constituents of the world are all that there is, and that higher-order realities such as the human mind and culture can ultimately be explained by the laws of physics and chemistry. Reductionists often point to the success of neo-Darwinism and the discovery of DNA as justification for their approach. Likewise, categories of mind and the human person, so reductionists argue, can best be understood in terms of the activities of the brain. In the late twentieth century, reductionism was most associated with the popular writings of Richard Dawkins and Francis Crick in biology and the thought of Daniel Dennett, Paul Churchland, and Patricia Churchland in the philosophy of mind.

Modern opposition to reductionism has early roots in the movement of British emergentism, typified by the work of C. D. Broad. Opponents to reductionism have frequently endorsed the category of emergence, arguing that there are higher-order levels that emerge from, but are not reducible to, the lower levels of reality. Generally speaking, emergentists do not deny the validity of the lower-level sciences, only their sufficiency for explaining higher-order phenomenon. Emergentism came to be particularly important for the defense of biology as a legitimate and separate field of inquiry from physics and chemistry, and has been vigorously supported by such prominent thinkers as biologist Ernst Mayr and philosopher Karl Popper. Emergence has also been complemented by the concept of supervenience, which provides a philosophical framework for understanding the relation of different levels of reality. Philosophers such as Jaegwon Kim have argued, however, that supervenience ultimately leads to causal reduction of higher-level to lower-level physical properties. Within the paradigm of computational complexity theory, a similar suspicion has been raised against emergence by John Holland and others.

Hierarchy in the science-religion dialogue

Science and religion scholars have tended to support emergentist positions and reject reductionist ontologies. Both the physicist and theologian Ian Barbour and the biochemist and theologian Arthur Peacocke have strongly criticized reductionist interpretations of science. Both have noted that while science employs methodological reductionism in its attempt to analyze physical reality, such practice does not entail ontological reductionism. Going a step further, Peacocke has argued that the whole of reality should be understood as a complex hierarchy that begins at the bottom with physics and chemistry, and moves towards increasing levels of complexity, moving towards living organisms, human beings, cultures, and eventually God at the very top. Peacocke's analysis has had tremendous influence, and has been developed in different ways by philosophers Nancey Murphy and Philip Clayton.

Despite this, the value of hierarchical thinking has been much questioned in broader theological circles. Feminist theologians such as Sallie McFague have criticized traditional moral hierarchies because of their tendency to oppress women. Environmental theologians and philosophers have also criticized moral hierarchies as contributors to abuse of animals and destruction of ecosystems. Because traditional moral hierarchies have been justified by reference to ontological hierarchies, these too have come under attack. Serious dialogue between these differing theological perspectives has yet to occur and represents a likely step in the science-religion dialogue.

See also EMERGENCE; HOLISM; ORDER; PLATO; SUPERVENIENCE

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HINDUISM

Unlike the Western religions, Hinduism does not have an easily identifiable beginning. Although records of its early history are not available, Hinduism dates back at least three thousand years in the subcontinent of India. However, within Hinduism there is a great diversity of practice and belief so that it is difficult to identify a distinctive essence. Hinduism contains many traditions that share distinctive characteristics such that they are identifiable as members of the same cultural family. Some traditions share more of these characteristics, making them more strongly Hindu. Over the centuries one such characteristic has been the practice of caste distinctions. Another is seeing Hinduism as a religious way of life that in one way or another reaches back to scriptures, the oldest of which is the Veda.

Historical origins

The term Hindu derives from the Indus River in the northwest part of the Indian subcontinent. Flowing some three thousand kilometers from the Himalayas to the Arabian Sea, the Indus served as a natural boundary for those attempting to enter India through the passes of the Hindu Kush. During the period 1500 to 1000 B.C.E., people known as the Aryans, who may have come through these mountain passes, began to dominant the Indus River area of northwest India. Their view of the world was described in the Veda, spoken and written in the Sanskrit language. In the oldest portion of the Vedas, called the *Rg samhita,* there are references to a river called the *Sindhu,* which may have been the Indus. By association, the word *Sindhu* seems also to have been used to refer to the people who lived in the Indus valley. The later term *Hindu* seems to have derived from *Sindhu*.

From the earliest historical times, military invasions and trade have flowed through the mountain passes of the northwest, such as the Khyber. Those who invaded India from the Mediterranean area (e.g., the Persian Darius I and Alexander of Macedon) used the term Hindu to refer to those who lived on or beyond the Sindhu River boundary. Over the centuries the term Hindu has increasingly been used to refer to those Indians who share some connection with the Veda as a basis for their way of life. Within the Vedic scriptures are found the overarching concepts of caste, karma, and rebirth that knit together the many diverse Hindu groups. Karma is the idea that each action or thought leaves behind a seed or memory trace that predisposes one to a similar action or thought in the future. These karmic traces, stored up in one's unconscious, as it were, originated not only in this life but also from previous lives, and cause one to be reborn in a future life. This cycle of birth, death, and rebirth is held to be beginningless (*anandi*) and is seemingly endless. However, for those wishing to escape from this cycle of rebirth, the Hindu scriptures offer three general paths or disciplines (*Yogas*) by which release may be realized: the paths of knowledge, work, and devotion. In orthodox or Brahmanical Hinduism, the source of these paths, and indeed of all knowledge, including science, is said to be the Vedic scriptures.

Cosmology and the concept of God

In the Hindu view, the whole of the universe is held to have existed beginninglessly as a series of cycles of creation going backward into time infinitely. Although the Hindu scripture is spoken anew at the start of each cycle of creation, what is spoken is identical with the scripture that had been spoken in all previous cycles. The very idea of an absolute point of beginning for either creation or the scripture is not present in Hindu thought. A close parallel to this Hindu notion of the eternal presence of scripture is found in the Western idea of the Logos, especially as expressed in the Gospel of John: "In the beginning was the Word, and the Word was with God, and the Word was God" (1:1). The *rsis* or seers, identified as speakers of particular Vedas, are understood to be channels through which the divine word passes to make itself available to humans at the start of each creation cycle. The same *rsis* are said to speak the same Vedas in each cycle of creation, and the very language in which the Vedas are spoken, Sanskrit, is itself held to be divine.

This view of the Vedas and Sanskrit as being divine had important implications for the traditional Hindu understanding of all forms of knowledge, including science. The *rsi's* initial mystical vision is of Brahman's consciousness, God's omniscient knowledge. This unitary vision is broken down and spoken as the words and sentences of the Veda so that through this revelation people will be enabled to realize release. In addition to this ultimate spiritual goal, the Veda, as the authoritative speaking of divine omniscience, contains in seed form the fundamental knowledge of all the disciplines—the arts, medicine, and science. This is why the Grammarian philosophers of India argue that correct word use (following Sanskrit rules) is essential for science for two reasons. First, it is essential because only when language is spoken and heard correctly will the seeds of scientific ideas inherent in the Veda be able to manifest themselves. Second, correct word use is essential in formulating and communicating scientific knowledge so that it does not become confused but is clearly conveyed.

Such thinking lies behind the traditional Hindu notion that all knowledge, including science, comes from and through the Vedas. It is just this kind of thinking that anchors the claim of the modern Hindu reformer Swami Vivekananda (1863–1902) that science and religion are complementary, cross-validating, and are both based on experience of the same Brahman. Just as science is based on the empirical experience of the outer world (whose essence is Brahman) so also religious knowledge arises from the direct experience of the Vedic word; at base both are experiences of the same ultimate reality.

See also KARMA

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HAROLD COWARD

HINDUISM, CONTEMPORARY ISSUES IN SCIENCE AND RELIGION

Modern science was brought to India during the 1800s by the British as a part of the colonization process. The goal of science in the colony was not the advancement of science but rather the exploration of natural resources, flora, and fauna to feed the needs and demands of Britain and its ongoing industrial revolution. In the colonial context of India there was also discrimination against deserving Indian scientists who were relegated to positions below their entitlement and paid half the salary of their British counterparts.

Scientists in modern India can be divided into three categories. First there were transplanted European scientists employed by the British government who served as "gatekeepers" of colonial science. In the second category were British scientific personnel called by the colonial administration to undertake specific tasks. They had no commitment to the advancement of science in India. When these scientists completed their assignments, they returned home taking with them their knowledge and experience. A third category was composed of Indian scientists who became prominent after the 1870s. They were supported by a small group of British settler scientists and Christian missionaries who devoted themselves to the establishment of professional science in India. They numbered a few hundred including such key persons as David Hare, Eugene Lafont, William Carey, Prafulla Chandra Ray, Jagadish Chandra Bose, Chandrasekhara Venkata Raman, Meghnad N. Saha, and Mahendra Lal Sircar. While scientists in the first two categories were part of the colonial enterprise, it was the third group that struggled to transform colonial structures and create an indigenous and autonomous culture of science in India.

Within Hinduism, during the same time period, the Hindu reformer Swami Vivekananda (1863–1902) was revising Hindu thought to accommodate European rationality and science. Among the Bengali intelligentsia of the late nineteenth century it was widely felt that science as a method of obtaining knowledge about humans and nature was the key to human progress. Therefore, all systems of thought, including religion, needed to be validated by reason and science. Following the lead of earlier Brahmo Samaj thinkers such as Keshub Chandra Sen (1838–1884), Vivekananda attempted to show the compatibility of Hindu Advaita philosophy with science. Continued efforts in contemporary Hindu studies to draw analogies between Advaita and science are evidence of Vivekananda's influence. Just as science allows for the discovery of physical laws through the application of the scientific method, so also said Vivekananda, the *rsis* or seers who wrote the Vedas are the discoverers of spiritual laws. Rather than depending for their authority on their status as revelation, the Vedas can be shown to be timeless impersonal laws (like the law of gravity) that one accepts not on the basis of faith but by testing out and proving for oneself in one's own experience (just as the scientist does in verifying, by experiment, the discoveries of others.) Thus, the Advaita teaching on the realization of knowledge of Brahman (*brahmajñāna*) is, according to Vivekananda, a method, like the scientific method, for the discovery of spiritual facts. Although one must begin with reliance on the Veda, one must eventually go beyond such a faith basis and prove the truths of the Vedas in personal experience. For Vivekananda, this method of attaining one's own spiritual knowledge is based on the Yoga of Patanjali (c. 200 B.C.E–200 C.E.), with its focus on the direct experience of truth, and is parallel to the process of attaining and verifying knowledge in science.

Following the lead of Vivekananda, Hindu philosophers and theologians typically see themselves as presenting an approach in which spiritual and scientific knowledge coalesce, and through which they can win back their selfhood. For Hinduism the European scientific and technological tradition cannot be ignored or rejected, but must be absorbed and "worked-through" until the heart of Hinduism is reclaimed. This "working-through" is manifesting itself in contemporary cosmology and applied sciences such as medicine, ecology, and genetic engineering.

Cosmology

Hindu thinkers approach the still unresolved mystery of the universe by looking back to Brahman (the Divine) as somehow associated with the creation or production of the universe. Scientific theory has speculated that the universe may arise from a quantum vacuum state, which is a peculiar mixture of emptiness and activity. Ancient sages, say Hindu thinkers, had similar thoughts. The Sanskrit concept of zero, when applied to Brahman, is identified with both fullness and emptiness. Zero also makes possible advances in mathematics and modern digital technology. The universe is ontologically characterized by the term *Brahman* from the root *brh* "to expand." The *risis* thought of the universe as an "expanding Brahman," which is consistent with contemporary cosmological thinking. The current idea of a Big Bang in which very dense matter explodes into an expanding universe is seen to be prefigured by the Upanishadic notion *bindu*—a dimensionless point that is a unity of both static and dynamic forces, the dynamic expressing itself as the universe of multiplicity while essentially remaining a unity or order (*rta*). Or, as cosmologists put it, about 100 billion stars, including the sun, make up the Milky Way galaxy, a spiral wheel-shaped structure. This galaxy is part of a group of galaxies that form a cluster, while clusters in turn form superclusters of many thousands of galaxies. Cosmologists suggest that this pattern of hierarchical clustering prevails throughout the cosmos with gravitational forces holding the whole thing together. This contemporary theorizing recalls the Upanishadic words of the *rsi* Yajñvalkya to his pupil Aruni: "This world and the next world and all beings and all natural phenomena are strung together by the thread, the Inner Controller, the Immortal, the Brahman." (Brhad-arañyaka Upanishad III:7:3).

The vast collection of Hindu scripture leaves ample room for speculations as to ancient Vedic precursors of the latest thinking in India's strong scientific traditions in mathematics and astronomy, represented by the outstanding twentieth-century mathematician, Srinivasa Ramanujan (1887–1920), and Chandrasekhara Venkata Raman (1888–1970), the 1930 Nobel prize winner in physics. As A. K. Bag shows, contemporary Indian excellence in mathematics and astronomy may be traced back to the Vedic concerns with the correct construction of strangely shaped altars and the correct astronomical time for the conducting of both individual and social events (p.186).

Medicine

British colonization brought to India modern Western medicine, where it met *Ayurveda* or traditional Indian medicine, which traces itself back to the Vedas. Modern medicine, and its assumption of René Descartes's mind-body dualism, has often viewed the body as a mechanical object to be exercised, fed, and kept in order with drugs and the miracles of modern technology. By contrast, traditional Indian medicine sees the person as a sacred entity, a microcosm corresponding to the whole cosmological order. Consequently all Hindu thinking about the person and, to take an example, one's reproductive activity takes place within the larger context of the divine-human cosmos. To study the health of the Hindu bather who goes to the river at daybreak, one must include the mantras chanted, the purifying experience of the body in water, the vegetarian *sattvic* quality of the food eaten, and so on—a gestalt of human-within-nature/culture/religion analysis. The Western mechanistic view of the isolated body was held by British medicine to be the scientific replacement for the sense of the healthy person as a unity of body, mind, and environment as maintained by Hindu medicine. In the attempted superimposition of British ways upon India, the colonization of the body by modern Western medicine was a key strategy, especially when it assumed the right to define health and illness, and a monopoly to treat the latter. This particular colonization did not succeed, however, for many Hindus continue to practice Ayurveda and homeopathy alongside modern biomedicine.

A second colonization of the body is that of the patriarchal social order that has dominated Hindu thought and practice from the seventh century B.C.E. to the present. This colonization of women and their bodies, when combined with modern medical technology, raises serious ethical issues for contemporary Hindus. Since the patriarchal biasing of Hindu culture has led some Hindus to value boys more than girls, clinics have appeared in India and in Western diaspora communities where sonograms and amniocenteses are performed, and female fetuses aborted, even though this practice finds no justification in Hindu texts unless the life of the mother is in danger. Given the Hindu teaching of reincarnation, to engage in abortion is to commit murder.

In the realm of new reproductive technologies, the importance of popular Hindu notions of biological descent entail that artificial insemination with sperm other than that of the husband is not tolerated. But clinics that can help a childless couple conceive by implanting the husband's sperm are welcomed. In vitro fertilization (IVF), however, presents complicated issues for Hinduism. Fertility is important, especially the conception and birth of a son. Thus IVF is attractive to couples having difficulty conceiving and giving birth. Although modern India is using IVF enthusiastically, when considered by Hindu scholars IVF becomes a serious issue since the destruction of any embryo is considered murder—thus all fertilized embryos are to be implanted. Hinduism has religious rituals that must be performed by a son if one's afterlife is to be secured, and the dowry practice makes sons a source of wealth and daughters a drain on family fortunes. Thus, the conflict between the desire for sons (and the possibility of ensuring them through the new technologies) and the proscription against abortion places severe moral strains on some families, especially upon the mothers involved.

Ecology

Hindu texts speak of a close relationship between dharma (righteousness, duty, justice) and the ravaging of the earth. When dharma declines, humans take it out on nature. Modern science and technology, introduced into India during the British colonization and fostered by Jawaharlal Nehru's plans to industrialize India (undertaken after Indian attained independence in 1947), have led to serious pollution of the rivers, land, and air. This has been made worse by the country's population explosion and the desire of India's well-off classes (estimated at 200 to 250 million people) to consume conspicuously. This overpopulation and overconsumption has led to serious environmental degradation and an ecological crisis. The challenge for future science and Hinduism is how to use the resources of both to foster a sustainable future for generations to come. A key Hindu text, the Bhagavad Gita, offers a vision of the universe as the body of God towards which Hindus are to behave with respect. In addition, there are dharma texts in the Ramayana, Mahabharta, and Puranas that call for ecological action. The destruction of forests is condemned and the planting of trees encouraged. Temples such as the Tirumala Tirupati in South India, a famous place of pilgrimage, have established large nursery forests and, in place of the traditional food *prasada* (favor of the deity which gives one divine grace), have begun to give saplings to pilgrims to take home and plant. Hindu gurus have begun to cite previously obscure texts such as "one tree is equal to ten sons." When political officials visit the temple they are given a tree to plant as a symbol that all trees are worthy of respect as part of God's body.

The Hindu tradition emphasizes bathing in rivers as a way to be morally cleansed and to acquire spiritual merit. Thus rivers, especially the Ganges, are seen as sacred. Rapid industrialization, however, has led to the release of toxic wastes into India's rivers. Overpopulation and the lack of basic sanitary facilities have resulted in the rivers being used as latrines despite the injunctions of dharma texts against such practices. Rivers that are supposed to be a pure part of God's body, and to be able to ritually purify people, stand stagnant due to dams and are polluted with waste—the results of *adharma* or unrighteous behavior. The Hindu view of rivers as nurturing goddesses is under severe challenge due to contemporary environmental degradation, which is linked by some scholars, such as Vasudha Narayanan, with the denigration of women. A comparison can be made between the plight of rivers and the plight of women, both being targets of greed and power. Yet it is women, as in the Chipko (hugging trees) movement, that are leaders in the protection of forests and the stopping of dams. Women are also involved in communicating the tragedy of ecological disasters using traditional religious art forms of song, dance, and story. The challenge for science is to join forces with such ecological movements within Hinduism so as to respond to the current crisis.

Genetic engineering

In hopes of responding to India's overpopulation and the attendant need for increased food production, both government and industry have turned to genetic engineering for help. Science in India has responded quickly with research ranging from genetic studies of the human population to various agricultural and medical applications. Such studies raise ethical questions for Hinduism. Pharmaceutical companies use the traditional genetic knowledge of village and tribal peoples, and then engineer and patent products for which the local people receive no credit and for which they have to pay. Similarly the genetic altering and patenting of seeds takes them out of the hands of ordinary farmers and places them under corporate control. For example, Monsanto in partnership with Mahyco (a seed company in India), has genetically engineered hybrid cotton seed to produce the Bacillus thuringiensis (Bt) enzyme, so that chemical insecticide sprays will no longer be needed for pest control (e.g., bollworms). While this may be beneficial for the preservation of insect diversity, more problematic has been the activity of Monsanto in India in testing the "terminator gene," which allows plants to grow but not produce seed for future crops. This led to protests by farmers' groups, ecofeminist activity by Vandana Siva, and charges of biopiracy against Monsanto. In the face of this protest the Indian government reversed its position and declared that the terminator gene will pose a serious threat to Indian agriculture. The government implemented regulations to cover every phase of genetic engineering from laboratory research to field trials and final release.

Such regulations, however, may not cover the important ethical questions that an application of Hinduism will raise. For example, given that all of nature is God's body, are there moral limits that genetic engineering must respect? Or do the requirements of dharma allow for the patenting and commercial (for profit) ownership of forms of life? And is the crossing of species in genetic engineering acceptable? Hindu answers to these questions may well differ from responses of the Western religions given the strong Hindu view (*karma-samsara*) that there is no radical separation between humans and other forms of life, which from a Jaina perspective extends from humans to animals, plants, air, water, and molecules of matter. Instead, a radical continuity is proposed that has ethical implications for much genetic engineering. Hindu reverencing of plant and animal life offers an important corrective to tendencies in modern science and technology to view the results of genetic engineering strictly from the perspective of the benefits that will accrue to humans. Although medical therapeutic uses of genetic engineering may, at first glance, seem more defensible, they are open to similar ethical examination. Although therapeutic goals seems more clearly good than enhancement goals (e.g., more intelligence, better memory), once one begins to make genetic modifications, one is unsure of the biological and social consequences for the individual and for the collective ecosystem of which the individual is but a part. While the government of India still looks to genetic engineering for help in feeding India's population of 950 million and growing, the Hindu peasant farmer still plants his seed with the prayer, "Let the seed never be exhausted, let it bring forth seed next year." The challenge to science is to help feed the hungry and heal the sick while still respecting the requirements of dharma or righteousness in which the farmer trusts.

See also ECOFEMINISM; ECOLOGY; SPIRITUALITY

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HAROLD COWARD

HINDUISM, HISTORY OF SCIENCE AND RELIGION

Hinduism is not the name of a particular religion in the narrow modern sense but it stands for a cultural tradition that developed over thousands of years on the South-Asian subcontinent, now embracing many different religions, such as Vaiṣṇavism, Śaivism, Śāktism, and others. Hinduism comprises, besides rituals and festivities and detailed ethical regulations for individuals and communities, also the arts and sciences. Hinduism never knew the Western antagonism between philosophy and theology, nor does it have a history of warfare between science and religion. It was the highest aim of Hindus to find *satyam,* truth/reality, which could be approached in many ways and appear in many forms.

The well organized, publicly sponsored ancient Indian universities such as those at Taxilā and Nālandā (considered venerable institutions already at the time of Gautama the Buddha [late sixth and early fifth centuries B.C.E.]), with thousands of teachers and tens of thousands of students, taught not only the Veda (revealed scripture) and the *Vedā·gas* (auxiliary disciplines), but also the "eighteen sciences." The basic curriculum included *śabda-vidyā* (linguistics), *Śilpasthāna-vidyā* (arts and crafts), *cikitsa-vidyā* (medicine), *hetu-vidyā* (logic and dialectics), and *adhyātma-vidyā* (spirituality). Religion, while suffusing all life and activity, was not isolated from other subjects or given exclusive attention. The *brahmins,* the custodians of the sacred texts, were also the leading intellectuals who studied and taught secular subjects.

Hindu scriptures and thought

The Hindus called their most ancient and most venerated scripture *Veda* (from the verbal root *vid-,* to know). *Vidyā,* from the same root, designated knowledge acquired in any subject (a medical doctor was called a *Vaidya*), particularly that of the highest reality/truth taught by the Upanishads. The term *śāstra* (from the root *śās-*, to order) became the most general designation for *science* (in the sense of French *science* or Italian *scienza*): authoritative, systematic teaching, ranging from *Dharmaśāstra,* the exposition of traditional law, and *Arthaśāstra,* the teaching of statecraft and administration, to *Śilpa-śāstra,* instruction in art and architecture, and *Kṛṣi-śāstra,* the theory and practice of agriculture. A learned person carried the title of *Śāstrī,* respected by the community regardless of the subject of his learning. Graduation was a "third birth": members of the three higher castes became *dvijati* (twiceborn) through *upanayana* (initiation), the śāstrī degree made them *trijati.*

Traditional Indian thought is characterized by a holistic vision. Instead of breaking experience and reality up into isolated fragments, the Indian thinkers looked at the whole and reconciled tensions and seeming contradictions within overarching categories. Thus the poets of the *Ṛgveda* speak of *viśva-jyoti,* cosmic light as the principle and source of everything, and of *ṛta,* the universal cosmic order connecting and directing all particular phenomena and events. The Upanishads organize the world by relating everything to the *pañcabhūtas* (five elements: earth, water, light, wind, ether) and identify in Brahman an all-embracing reality-principle. The name of the major deity of later Hinduism is *Viṣṇu,* the "all-pervading," whose body is the universe. Nature (*prakṛti*) was never seen as mere object, but always as productive agent. The Hindu view of life found expression in the four *puruṣārthas*: a person was to acquire wealth (*artha*), enjoy life (*kāma*), practice morality and religion (*dharma*), and seek final emancipation (*mokṣa*) in appropriate balance. Religion was a natural part of the universally accepted order of things. Texts dealing with medicine contain religious regulations, and theological treatises also frequently refer to worldly matters. The study of *Nyāya* (logic and epistemology) was undertaken to achieve *mokṣa* (spiritual emancipation). The notion of *atman* was applied to humans, animals, and plants. Many Indian scientists show an interest in religious issues, and Hindu spiritual leaders frequently appeal to science to illustrate their instructions. They would never relegate science to pure reason and religion to pure faith and treat them as natural enemies, as is often done in the West.

According to the Vedas, only one-fourth of reality is accessible to the senses, which also include *manas,* instrumental reason. Supersensual reality revealed itself to the *ṛṣis,* the composers of the Vedic *sūktas.* The Upanishads know an ascending correlation of subject/consciousness and object/reality: Only the lowest of four stages (*jāgarita*) concerns sense perception of material objects. The three higher levels of reality are intuited through meditative introspection, which culminates in the insight that *ātman* is Brahman: Spirit-self alone is supreme reality.

The central ritual of Vedic culture was the *yajña* (sacrifice of material objects according to fixed rules). *Brahmin* students had to train for many years to learn to perform *yajña,* which involved, besides the priest and the patron, the *devas* (the deities of earth, space, and heaven who were invited to attend). It was offered on altars built with specifically produced bricks arranged in a prescribed geometric pattern, performed at astronomically fixed times. The altar was conceived as symbol of the human body as well as of the universe: One text relates the 360 bricks of an altar to the 360 days of the year and the 360 bones in the human body. The building of altars of different configurations, and more so their change in shape and volume, as required in certain rituals, involved a sophisticated geometry. *Śulva-sūtras* (part of *Kalpa-sūtras,* ritual texts) provided the rules for constructing a variety of shapes of altars and their permutations. They exhibit an algebraic geometry older and more advanced than early Egyptian, Babylonian, or Greek geometry. The exact timing of the performance of the sacrifices was accomplished by people conversant with the movement of the stars. *Jyotiṣa,* one of the six early *Vedā·gas* (auxiliary sciences of the Veda), reveals a good deal of astronomical knowledge.

Study was mandatory for *brahmins.* They had to devote the first part of their lives up to age twenty-four to systematic training under the supervision of a *guru.* Later they had to practice *svādhyāya* (study on their own.) While the study of the Vedas and the *Vedā·gas* was reserved for *brahmins,* the study of the *Upavedas* was open to all higher castes. These comprise *Āyur-veda* ("life-science," medicine), *Dhanur-veda* ("bow-science," martial arts), *Gandharva-veda* ("art-science," music and dancing), and *Stāpathya-veda* ("building science," architecture, sculpture, and painting). The universities, where these subjects were taught, attracted a large body of students from all over Asia. Reports from fourth and sixth century Chinese guest-students praise the physical amenities as well as the high standard of learning. In the eleventh century, after the Muslim invaders had already destroyed much of India's cultural infrastructure, the Muslim scholar-diplomat Al-Biruni spent a decade in India researching and documenting many aspects of traditional Indian science in his *Al-Hind.*

The practical sciences of Hindu India

Research in the history of Indian science is still in an early stage and much work remains to be done. New material is regularly published in the well established *Indian Journal for the History of Science, Vedic Science,* and other periodicals. In the following, elementary information is offered on some specific areas only. The dates for early Indian literature are still a matter of controversy; expert opinions often differ by thousands of years.

Astronomy. Astronomical knowledge of a fairly high order was required for the performance of Vedic *yajñas.* According to Subhash Kak, the structures both of the *Ṛgveda* text and the Vedic altars contain an "astronomical code," embodying precise and fairly accurate information about distances and revolutions of planets and more general astronomical data. The *Ṛgveda* has some astronomical markers that have been used for dating these texts to the fourth millenium B.C.E. From the *Jyotiṣa Vedā·ga* (third century B.C.E.) onwards there is a rich Indian astronomical literature. Indians operated with various cycles of lunar and solar years and calculated cosmic cycles of 10,800 and 432,000 years. Their findings and theories are embodied in numerous *siddhāntas,* of which the most famous is the *Sūrya-siddhānta* (fourth century C.E.). Indian astronomers calculated the duration of one *kalpa* (a cycle of the universe during which all the heavenly bodies return to their original positions) to be 4,320,000,000 years. Several *Purāṇas* contain cosmogonic and cosmological sections utilizing astronomy, describing periodic creations and destructions of the universe, and also suggesting the existence of parallel universes. While the main purpose of the *Purāṇas* is to recommend a specific path of salvation, this is always set into a cosmic context. Many popular *stotras* (hymns, prayers) recited at religious gatherings allude to cosmic events as well. One of the most interesting figures among Indian astronomers is Varāhamihira (fifth to sixth century C.E.), the author of the celebrated *Pañcasiddhāntika amd* of the *Bṛhat-Saṃhitā,* which besides astronomical information teaches astrology and all kinds of occult arts.

Mathematics. Indian mathematics developed out of the requirements for the Vedic *yajña*. The *Yajurveda* knows terms for numbers up to 10^{12} (by comparison the highest number named by the Greeks was 10^4). Later on the Indians coined terms for numbers up to 10^{24} and 10^{53}. Algebra, in spite of its Arabic name, is an Indian invention, and so are the zero and the decimal system, including the "Arabic" numerals. The names of some great Indian mathematicians and some particulars of their accomplishments are known. Thus Āryabhaṭa I (fifth century C.E.), a link in a long chain of unknown earlier master mathematicians, knew the rules for extracting square and cubic roots. He determined the value of π to four decimals and developed an alphabetical system for expressing numbers on the decimal place value model. His *Āryabhaṭīya* was translated into Latin (from an Arabic translation) by a thirteenth century Italian mathematician. Brahmagupta (seventh century C.E.) formulated a thousand years before the great Swiss mathematician Leonhard Euler (1707–1783) a theorem based on indeterminate equations. Bhāskara II (twelfth century) is the author of the *Siddhānta-śiromaṇī,* a widely used text on algebra and geometry. Hindus have continued to show great aptitude for mathematics. Ramanujan (1887–1920), practically untutored, developed the most astounding mathematical theorems.

Medicine. The *Atharva-veda,* considered by some to be the oldest among the four Vedas, contains invocations relating to bodily and mental diseases. Its *Upa-veda,* the *Āyur-veda* (life-science) was cultivated systematically from early on. It was mainly oriented towards preventing diseases and healing through herbal remedies, but it also later developed other medical specialties. Good health was not only considered generally desirable, but also priced as a precondition for reaching spiritual fulfillment. Medicine as a charity was widely recommended and supported by the rulers. Two Indian medical handbooks, the result of centuries of development, became famous in the ancient world far beyond India: the *Caraka-saṃhitā* and the *Suśruta-saṃhitā*. They were later translated and utilized by the invading Muslims. Caraka deals mainly with general medicine and identifies hundreds of medical conditions for which mainly plant pharmaca are prescribed. *Suśruta* focuses on surgery, which by that time was already highly developed, with an array of specific surgical instruments. Indian surgeons were famous in the ancient world; their skills were especially appreciated by the wounded in the frequent wars. Hindus also called upon the divine physician of the gods Dhanvantari, "the one who removes arrows." The theory of *Āyurveda* was based on the *tri-doṣa* theory, which is older than the similar Greek three-humours teaching, used for diagnosis as well as in the treatment of diseases. While the healthy body has a perfect balance of *vata, pitta,* and *kapha,* disease is a disturbance of that harmony, to be cured by re-establishing the right proportion.

Āyur-veda was also applied to animals and plants. There is an ancient *Vṛkṣāyurveda,* a handbook for professional gardeners, and a *Gāvāyurveda* for veterinarians of cattle. Other texts deal with veterinary medicine relating to horses and elephants. Ancient India also had hospitals as well as animal clinics, and *gośalās,* places in which elderly cattle are tended, are still popular in some parts of India. *Āyurveda* was the source of much of ancient Greek and Roman, as well as mediaeval Arabic, medical knowledge. The scientific value of Āyurvedic pharmacology is being recognized by major Western pharmaceutical companies who apply for world-wide patents on medicinal plants discovered and described by the ancient Indian *Vaidyas.*

Architecture. The ancient Indus civilization exhibits a high degree of architectural achievement. The well-laid out cities, the carefully built brick houses, the systems of drainage, and the large water tanks reveal the work of professional town-planners and builders. This tradition was continued and enhanced in later centuries, especially in connection with the building of temples to provide abodes for the deity. No village or town was deemed fit for human habitation if it did not possess a temple. Careful selection and preparation of the ground preceded the building activity proper. The edifice had to be constructed according to an elaborate set of rules that took into account not only structural engineering and quality of materials, but also circumstances of caste and religious affiliation. The Upaveda of *Sthāpatya-vidyā* was expanded into a professional *Vāstu-śāstra* and *Śilpa-śāstra.* Elaborate handbooks like the *Mānasāra* and the *Mayamata* provide detailed artistic and religious canons for the building of temples and the making of images. Temples and images of deities were consecrated only if they conformed to the standards established. The temple (*maṇḍira*) was a visible symbol of the universe, showing the entire range of entities from the highest to the lowest. The image (*mūrti*) was the very body of God, who descended into it for the purpose of receiving worship. Thousands of large and beautiful temples dot the landscape of India, and millions of images adorn *maṇḍiras* and homes.

Linguistics. While India's medical doctors, architects, metallurgists, mathematicians, astronomers, and others were appreciated for their knowledge and skills in their fields, the pride of place in the world of brahminic knowledge always belonged to the study of the Word (*vāk*), which from early on was seen as embued with divine power. The *brahmins* who preserved and investigated the Word occupied the highest social rank. Sanskrit, the refined language of the Veda and of higher learning, was considered a gift of the gods.

The Sanskrit alphabet, in contrast to the chaotic alphabets used in Western languages, is based on a scientific system: All vowels are arranged in an orderly fashion according to acoustic principles. The consonants are organized in five classes (guttural, palatal, cerebral, dental, labial) and, in each of these, five varieties were distinguished (hard, hard-aspirate, soft, soft-aspirate, nasal). This system shows great ingenuity and a keen sense of observation and proved conducive to formulating general grammatical and phonetical laws. It was in place already by one thousand B.C.E. By six hundred B.C.E., Pāniṇi, a linguistic genius of the first order, systematised Sanskrit in his *Aṣṭādhyāyī* by deriving all verbs and nouns from about eight hundred roots and formulating four thousand interconnected grammatical rules—an achievement unparalleled in any other language until the twenty-first century. Pāniṇi was followed by a long line of commentators, who continued his work: The best known is Patañjali, the author of the *Mahā-bhāṣya.* Traditional Indian scholarship was based on memorizing enormous amounts of literature and transmitting it orally over thousands of years. In the process Indians developed very sophisticated mnemotechnical devices.

Ancient Indian theoretical sciences

Among the *ṣaḍ-darśanas,* the traditional "six orthodox philosophical systems" of Hinduism, *Sāṁkhya* stands out as possibly the oldest and certainly the most interesting in the religion and science context. It offers a general theory of evolution based on the interactive polarity of nature and matter (*prakṛti*), and spirit and soul (*puruṣa*). All reality is subsumed under five times five principles (*tattvas*), originating from one substratum (*pradhāna*), covering all possible physical, biological, and psychological categories. *Sāṁkhya* shows the interconnections between the various components of our world in order to unravel the evolutionary process (which is seen as the cause of all unhappiness and misery) and to return to the changeless bliss of spirit-existence. The twenty-five categories to which *Sāmkhya* reduces the manifold world became widely accepted in Hindu thought. The *Yoga* system of Patañjali is wholly based on it. The *Purāṇas* also accept it as their philosophical basis, with one amendment: *Prakṛti* and *puruṣa* are overarched by *īśvara,* a personal creator-maintainer-savior God.

Vaiśeṣika, another one of the six orthodox *darśanas,* offers a theory of atomism more ancient than that of the Greek philosopher Democritus, and a detailed analysis of *viśeṣas,* qualities and differences, after which the system is named. The *Vaiśeṣika-sūtra* describes the formation of physical bodies from atoms (*aṇu*) through dyads (*dvyāṇuka*) and triads (*tryāṇuka*) in a strict cause-effect series. The positioning of the atoms determines the qualities of a body. *Vaiśeṣika* also developed the notion of impetus, a concept that appeared in Western science only in the fourteenth century. In *Vaiśeṣika* the relation of science to religion is less clear than in the case of *Sāṁkhya.* However, the other *darśana* with which it has been paired, *Nyāya,* concerned with epistemology and logic, declares that such analysis is necessary for obtaining spiritual liberation.

Spiritual sciences

Among the prescribed subjects of the ancient Indian university curriculum was *adhyātma-vidyā,* the science relating to spirit. As the most important level of reality, *Brahman* was the subject of the highest science, employing personal experience (*anubhāva),* a coherent epistemology (*yukti*), and the exegesis of revealed utterances (*śruti* or *śabda*). The Upanishads mention thirty-two *vidyās,* paths leading to the goal of all science: "One who knows *Brahman* becomes *Brahman.*" The ideas of the Upanishads were further developed into the systematics of Vedānta philosophy laid down mainly in commentaries (*bhāsyas*) on the *Brahma-sūtras* ascribed to Bādarāyaṇa (second century B.C.E.). Beginning with Śa·kara (eighth century C.E.), through Rāmānuja (eleventh century) to Madhva (thirteenth century), the greatest minds of India have endeavored to cultivate science that concerns itself with the eternal reality of the spirit. *Yoga* too, in the form in which it was systematized by Patañjali (*Rāja-yoga*) is proceeding scientifically by analyzing the world of experience in terms suitable to spiritual enlightenment and describing experiential steps to be taken to find enlightenment.

India's spiritual fame in the West is of long standing. During the fourth century B.C.E., Alexander the Great, intrigued by the proverbial wisdom of the *brahmins,* sought out the company of what the Greeks called *gymnosophists* on his Indian expedition (eventually replacing his mentor Aristotle by Kálanos, an Indian sage). Six centuries later, the philosopher Plotinus joined the expedition of Emperor Gordian in order to meet the famed Indian sages. No less a modern Western scientist than Austrian physicist Erwin Schrödinger (1887–1961), who won the Nobel prize for physics in 1933, has paid tribute to that "other" science: "The subject of every science is always the spirit and there is only that much true science in every endeavour as it contains spirit" (p. 495).

India and scientific technological progress

Glazed pottery appeared in Mohenjo Daro fifteen hundred years earlier than in Greece. Indian steel was so famous three-thousand years ago that the ancient Persians were eager to obtain swords from India. Indian silk and cotton fabrics were among the most prized imports of ancient Rome. The famous Iron Pillar in Delhi, almost eight meters high and weighing more than six tons, has weathered more than fifteen hundred monsoons without showing a trace of rust. Amazing engineering feats were displayed in the construction of numerous temples of huge dimensions. The capstone of the Bṛhadīśvara temple of Tanjavur, weighing eighty tons, was moved up to a height of sixty-five meters in the eleventh century. The skills of ancient Indian craftsmen, who created innumerable tools and works of art from ivory, wood, metal, and stone, show a broad based technical culture that had few equals in its time.

Many of the intellectual or practical achievements later ascribed to the Babylonians, the Greeks, or the Arabs had originated in India. India was the envy and the marvel of the ancient world before it fell victim to Muslim invaders, who massively disrupted its cultural, scientific, and religious traditions. The British who succeeded them encountered a weak, backward, fragmented, and demoralized India. Together with machine-made fabric, British India imported Western education and with it a hitherto unknown tension between culture and religion. Modern science and technology were touted as an accomplishment of Christian Europe and seen as the most effective instruments in overcoming superstitious Hinduism. Ram Mohan Roy, an early Hindu reformer, believed in the possibility of harmonizing Hinduism with modern Western science and the teachings of Christ. He founded English-language schools in which modern Western scientific knowledge was taught. Swami Dayanand Saraswati asserted that the ancient Hindus had known the principles of Western science long ago, had anticipated some of the technological marvels like steam-engines and airplanes, and did not need a new religion. He founded a traditional *Gurukula* with Sanskrit medium and only traditional Indian subjects. By the late twenty-first century, there are thousands of Indian scientists with a Hindu background. Most do not see a conflict between their religion and their science, but some do notice a difference in orientation. Some have been led to astounding discoveries through the application of ancient Hindu insights to new fields of enquiry. Thus the biologist Jagdish Chandra Bose (1860–1937) used the Upanishadic idea of the universal *ātman* to conduct groundbreaking research in plant physiology. The traditional Hindu holistic and personalistic orientation could serve as a necessary corrective to mainstream Western science with its Cartesian legacy of an impersonal mechanistic worldview and a purely pragmatic, analytic approach to nature.

See also ASTRONOMY; MEDICINE; SPIRITUALITY

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HISTORICAL CRITICISM

It would be difficult to argue that there was extensive interrelation between the rise of historical criticism and the emergence of modern science. True, both of these developments raised the most serious questions about the viability of traditional theological notions. In addition, the growing confidence in scientific explanations for events in nature, especially from the Enlightenment on, clearly eroded trust in traditional biblical authority. Yet the languages and the trajectories of criticism and science were mainly independent and parallel, as if taking place on the opposite sides of a high fence. And they raised different kinds of problems for the theological enterprise.

Method

Historical criticism of the Bible, sometimes referred to as *higher criticism* in contrast to the *textual criticism* that sought to determine the most accurate reading (or original texts) of the received biblical documents, sought to apply to the scriptures the same sort of analysis commonly used for other (especially ancient) literary documents—though it should be said that biblical scholars contributed perhaps more than any others to the origin and refinement of this kind of literary analysis. Prescinding from the traditional notions about authorship and "inspiration," historical criticism sought to answer anew questions about the origin and development of the scriptural literature, both by internal analysis and by relating the biblical texts to other records of ancient times. Fresh attention was given to such questions as: What is the relation of the biblical books to each other? How and why were they written? By whom? When? What did the writers intend to say? Were there historical causes that might account for the events recorded in the scriptures?

While such methods had been employed even in ancient times by some opponents of the church and by a small minority of Christian scholars, biblical studies in the church had continued to be largely insulated from literary criticism or defensive in reaction to it. Historical criticism began to be most extensively employed after the Renaissance and Reformation. The multiple levels of medieval interpretation, especially the allegorical or spiritual meanings, which through the Middle Ages had been favorite means of dealing with apparent difficulties and contradictions in the texts, were largely abandoned in favor of the "plain" or literal sense. In connection with their insistence on the authority of scripture rather than tradition, the Reformers, especially Martin Luther and William

Tyndal, had argued (though not consistently) for the "plain meaning."

Evolution of historical criticism

Early landmarks in the rise of historical criticism can be found in Thomas Hobbes's *Leviathan* (1651), with the implication that the Bible was not the word of God but rather contained the record of some men who had been inspired by God, and with doubts about the Mosaic authorship of the Pentateuch. Similarly, Baruch Spinoza, in the *Tractatus Theologico-Politicus* (1670), discussed the literary incoherencies, the historical contradictions, and chronological difficulties in Genesis. Spinoza was followed by the French oratorian Richard Simon (1638–1712), who noted the double accounts of some events in the Pentateuch and suggested a diversity in authorship, as well as the late origin of the present form of the Old Testament (i.e., only after the Exile). Simon is thus sometimes hailed as the true founder of historical criticism.

Application to the Old Testament. The full development of such criticism, however, came in the eighteenth and nineteenth centuries. Because the early application was mainly to the Hebrew scriptures, it was thus less threatening to Christian sensitivities. That criticism did not actually function much in the early adjustments to scientific (especially geological) views of the age of the world—for example, the notion popularized by James Ussher (1581–1656), the Irish Archbishop of Armagh, that creation had occurred in 4004 B.C.E., was easily abandoned by reinterpretation of the "days" of creation in the Genesis story. Yet historical criticism did raise serious questions about the reliability of the Old Testament chronology. And the uniformitarianism of the new geology of James Hutton in the eighteenth century and Charles Lyell (especially Lyell's *Principles of Geology,* 1830–1833) in the nineteenth century gradually replaced the popular catastrophism as a theory for the development of the earth. Equally important was reinterpretation of the nature of the Old Testament writings in general. For example, Johann Gottfried von Herder's *The Spirit of Hebrew Poetry* (1782–1783) and *History of the Education of Humanity* (1774), reflected both the Enlightenment critique of religious authority and the newly emerging Romantic movement. This was both parallel to and in protest against the Enlightenment (and especially Kantian) emphasis on the sole authority of the moral in religion.

Analysis of the sources and development of the Old Testament writings can be said to culminate in the Graf-Wellhausen theory (1876–1877) of the composition of the Hexateuch (the first six books of the Old Testament), which came to dominance by the end of the nineteenth century. To the basic distinction between the names for God in the *J* (Jahvist) and *E* (Elohim) sources were added the *D* (for Deuteronomic) and *P* (for Priestly) sources. Thus the famous *JEDP* documentary hypothesis, with subcategories in each (for some scholars).

It is of special interest that the biblical critical analysis played little or no role in Friedrich Schleiermacher's contention in *Der Christliche Glaube* (The Christian faith, 1821) that the Genesis stories of the creation and fall had no proper place in the Christian doctrines of creation and sin because those doctrines had properly to be derived strictly from the fundamental experience of utter dependence on God. Thus, for example, the controversy over whether creation is eternal or temporal has no bearing on the content of the feeling of utter dependence and is therefore a matter of indifference. On the other hand, it is plain that the scientific view of the world, or Nature, as a system of interconnected causality is crucial, and it is this which must go back to the divine causality as an explanation of the feeling of utter dependence. Thus cosmology is given over to the scientific view of things, yet the integrity of the religious affirmation is preserved, in what Schleiermacher in the second of his famous letters 1829 to his friend Friedrich Luecke called "an eternal covenant between the living Christian faith and a free, independent scientific inquiry, so that faith does not hinder science and science does not exclude faith" (p. 64). This statement has sometimes been hailed as the precursor of a fundamental dichotomy between the interests of theology and those of natural science that frequently appeared in the nineteenth and twentieth centuries.

Application to the New Testament. The application of the historical-critical method to the life of Jesus really began with German philosopher Hermann Samuel Reimarus (1694–1768), some of whose writings were published by Gothold Ephraim Lessing in the *Wolfenbuettel Fragments*

(1777–1778). This became the center of violent controversy with David Friedrich Strauss's *The Life of Jesus, Critically Examined* (1835). For both of these authors, of course, it was clear that certain events could not have happened in the way they were described in the gospels, because those accounts contravene scientific explanation. Strauss lists this as the first of his "negative" criteria for identifying the nonhistorical account; along with either internal inconsistency or contradiction to other accounts, a narrative can be "irreconcilable with the known and universal laws which govern the course of events" (p. 88). In this way, a scientific view is presupposed by historical criticism.

Closely related to this kind of argument was the rejection of the favorite traditional arguments from miracle and prophecy. The latter was partly a product of biblical criticism, with the recognition that the so-called prophecies in the Old Testament were properly to be understood in relation to current events rather than, for example, to the appearance of Jesus. The rejection of the argument from miracle was classically expressed in David Hume's critique in section ten of *An Enquiry Concerning Human Understanding* (1748). The argument here was not strictly a denial of the possibility of miracle, as a violation of the laws of nature, but was a devastating attack on the evidential value of such claims. Assumed here, but only in a general way, is the view of natural science as the primary explanatory category.

The historical-critical trajectory with respect to the New Testament continued particularly through varying analyses of the relations of the synoptic gospels, with the most widely accepted view that Luke and Matthew were dependent on Mark and that John was of much less value as an historical account. A culmination of this process was the judgment by the end of the nineteenth century that it was impossible to write a genuine biography of Jesus, for, as one fairly conservative thinker, Martin Kaehler, put it in 1892, we have "only a vast field strewn with the fragments of various traditions" (p. 49) out of which no sure account of the life of Jesus can come.

The most extreme case of the separation of science and theology was doubtless found in the work of the German liberal Protestant theologian Wilhelm Herrmann (1846–1922). Not only was natural scientific study irrelevant to the interests of religion, though within their limits the methods and results of science were "unassailable." Even metaphysics had to be rejected. So also "historical science," while it could serve the purposes of eliminating "false props" for faith, could have no positive value at all for the certainty or "full assurance" that faith requires.

See also SCRIPTURAL INTERPRETATION

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CLAUDE WELCH

HOLISM

Holism is any attitude toward explanation that places emphasis on the importance of a whole system as against that of its individual parts. *Holism* is thus an epistemological term, reflecting a particular approach to explanation. The term was first used in English by South African statesman and author Jan Christiaan Smuts in 1926. Its roots within Western philosophy, however, go back to the German thinker George Wilhelm Friedrich Hegel (1770–1831), with his insistence that "the truth is the whole."

The concept of holism is important to three areas of the science-religion debate: (1) in the philosophy of science, where it is in particular tension with falsificationism; (2) in considerations of causation, including divine action, where holism is in tension with reductionism; and (3) in ecological thinking, where it is in tension with dualism and anthropocentrism.

Holism in the philosophy of science rests on an insight initially developed by Pierre Duhem (1861–1916), and refined by W. V. O. Quine (1908–2000), to the effect that scientific theories face the bar of experience as a whole, as a complex web of interrelated postulates and hypotheses. When an experimental result conflicts with current theory, proponents of the theory have a wide choice as to which elements to re-evaluate, not only altering the hypothesis being tested, but rejecting the result as an artifact, rejecting the apparatus as inappropriate, questioning the mathematical framework used to draw inferences from the result, or altering other hypotheses to fit the data. This runs counter to Karl Popper's proposal that science unfolds by a process of empirical falsification of discrete hypotheses.

Holism in the debate about causation

In discussions of holism and causation it is necessary to mention an important result in quantum theory, as well as a wider debate as to whether systems in any way cause the behaviour of their parts.

Quantum holism.

It is a remarkable feature of the mathematical framework of quantum mechanics that all the elements of an interacting system must be considered together. The wave function of all the components of a quantum system is collapsed by contact with an act of measurement, which gives rise to a definite behavior in all the particles concerned, be they electrons, photons, or some other particle. Thus, measurement of an electron's spin could simultaneously determine the spin of another electron with which it had once been paired, even if the second particle were on the other side of the universe. However, the EPR Paradox proposed by Albert Einstein and colleagues in the 1930s challenged this view. The experimental vindication of the predicted quantum result by physicist Alain Aspect in 1982 confirmed that reality must be viewed as more interconnected than classical science would have supposed. The Aspect result has given rise to highly speculative proposals, including explanations for telepathy. The precise implications of nonlocal interactions between quantum particles remain unclear.

Whole-part causation.

Can the behavior of individual elements of a system be influenced by the character of the larger system of which they are a part? That the answer to this is "yes" can be demonstrated in quite simple chemical systems, such as the Bénard cell, where coordinated geometric structures form when a liquid is heated in a certain way. A commonsense view of conscious agency might suggest that this sort of causation is also present when a person decides to move his arm. Donald T. Campbell and Roger W. Sperry developed the concept of *top-down causation* to describe instances in which larger wholes constrain the behavior of their components. This remains a contentious area of debate, especially in the study of the mind-brain relationship, where it focuses on the question as to *what* is doing the causing, other than the component neurons of the brain.

However, few thinkers would not concede that complex entities such as the cell, the multicellular organism, and the ecosystem, do have to be described in terms of *emergent properties,* types of explanation not necessary for lower levels of complexity. For example, molecules such as hormones are sent round the human body as "messengers," reflecting the state of the body as a whole. These messages change the state of molecules within the cells they reach. Moreover, the science of chaos emphasises that the behavior of many important types of systems, from the weather to the human heart, is exquisitely sensitive to the boundary conditions of the system. These considerations limit the effectiveness of scientific reductions, efforts to describe complex phenomena in terms of their component parts. The attempt to effect such reductions is essential to scientific methodology, but the experience of science is that explanations in terms of the functioning of larger wholes remain indispensable.

Two words of caution are in order in developing holistic accounts of causation. First, the previous paragraph simply states that description in terms of wholes influencing parts is a necessary explanatory device within scientific epistemology. It does not, however, establish an ontology of efficient causes of the sort to which the physics of forces lays claim. Second, sensitivity to initial conditions shows how important the overall environment is to chaotic systems; even a tropical rainforest is a whole within larger wholes.

John Polkinghorne and Arthur Peacocke have taken a lead in proposing that top-down causation can function as an analogy for the activity of God within the created order. Polkinghorne has focused on the mathematics of chaos as indicative of the flexibility and openness of creation to the input of divine information. In response to criticism that the equations of chaos are fundamentally deterministic, he speculates whether they may only be approximations to a more holistic account of reality. Peacocke's emphasis is, rather, on (1) the hierarchy of emergent properties of the universe and (2) that assertion that interaction between God and human minds is the highest known level of that hierarchy. Peacocke's terminology for the sort of physical causation to which divine action might be analogous has shifted from *whole-part causation,* to *whole-part constraint,* and finally to *whole-part influence.*

The words of caution above show the difficulties of the analogy. There is no model for how wholes can be causally effective, other than through the causal interactions of their components, and there are no wholes in the cosmos that are not themselves wholes-within-environments. Models of divine agency that stress whole-part causation do no more than indicate that two analogies may be somewhat helpful: the analogy of human mind-in-body conscious agency, and the analogy of God as the environment of the world.

Holism in ecological thinking

Discussions of holism in ecology draw on American naturalist Aldo Leopold's *Sand County Almanac* (1949), in which he emphasizes the importance of the overall health of the biotic community. These discussions also draw on the insistence of Norwegian philosopher and ecologist Arne Naess as to the need for a "deep-ecological" attention to the whole network of relationships in an ecosystem. These emphases marked an ethical shift away from a focus on the interests of humans (anthropocentrism), and towards a sense that humans are no more than one part of the natural world. This sense is thus in tension with any dualistic view of humans that values only the status of their souls.

The understanding of the relation between humans and the nonhuman world is a major interface between scientific exploration of ecosystems and religious and ethical perspectives. The deep-ecological emphasis on the moral status of whole systems serves as a provocative corrective to the assumption that environmental problems can be best resolved by hierarchical, technocratic thinking. However, such holism raises an important question in environmental ethics: Is the whole system—be it the Brazilian rainforest or the total biosphere of the planet—the overriding locus of value, to which other values, such as the aspirations of individual humans, should be sacrificed? At their most radical such views smack of "ecofascism," and are themselves reductive of the complexity of biological systems. An alternative view is that of Holmes Rolston III, who asserts that the system is valuable because it is the protective matrix within which other sorts of value can be exchanged. Duties to a whole ecosystem, as Don Marietta insists, supplement, rather than supplant, duties to humans and other living things.

Holism is an important ingredient in a network of philosophical and physical explanations; it becomes weakened when its adherents neglect the importance of causative and evaluative explanations in terms of the components of systems.

See also BOUNDARY CONDITIONS; CHAOS THEORY; DOWNWARD CAUSATION; ECOLOGY; EPR PARADOX; HIERARCHY; PHYSICS, QUANTUM

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CHRISTOPHER SOUTHGATE

HOLY SPIRIT

The term *Holy Spirit* occurs in only two historically late texts in the Old Testament (Isa. 63:10.11; Ps. 51:13), but much can nonetheless be deduced about the term. God's spirit (*ruah Yahweh*) is the "wind," the breath of life, which proceeds from and will return to Yahweh. It determines life spans (Gen. 6:3; Ps. 104:29–30; Job 33:4) and tames natural forces (Ex. 15:8). Psalm 33:6 ("by the word of the Lord the heavens were made, and all their host by the breath of his mouth"), uses it synonymously with *word* (*dabar*), which Genesis uses to explain how God created the world.

God's spirit is not just a life-giving power. Job 32:8 includes the assertion, "But truly it is the spirit [*ruah*] in a mortal, the breath [*neshamah*] of the Almighty, that makes for understanding." God's spirit leads to wisdom and imparts exceptional qualities. To tackle a threatening famine, for instance, Pharaoh looked for someone "in whom is the spirit of God" (Gen. 41:38). The spirit of God can also endow "ability, intelligence, and knowledge in every kind of craft" (Ex. 31:3). Only the spirit of God leads to right living and fulfillment of the will of God (Ps. 51:10–10).

The New Testament retains the Old Testament notion that the spirit of God can perform unusual deeds and is an eschatological sign (Matt. 12:28). Similar to the creation of the world, God now generates a new creation through the spirit (*pneuma*: Matt 1:18; Luke 1:35). While Matthew and Mark seldom mentioned the Holy Spirit, Luke believed that the presence of the spirit characterizes the time of the church. At Pentecost the Holy Spirit filled the disciples (Acts 2:4), and all who are baptized receive the Holy Spirit. Through the identification of God with the spirit, the latter assumes a cosmological function for John: "God is spirit, and those who worship him must worship in spirit and truth" (John 4:24). The spirit is also the life empowering factor: "It is the spirit that gives life, the flesh is useless. The words that I have spoken to you are spirit and life" (John 6:63). Paul, too, identified Jesus Christ with the spirit and wrote: "Now the Lord is the Spirit, and where the Spirit of the Lord is, there is freedom" (2 Cor. 3:17). Unlike Gnosticism, the spiritual and the physical are not opposites but are unified because of Christ's resurrection (1 Cor. 15:44).

The Church Fathers saw a unity between the *logos* (word) that became flesh, the *pneuma* (spirit), and the *sophia* (wisdom) of God. The Council of Constantinople (381 C.E.) clarified the function of the Holy Spirit. It asserted that Jesus Christ "was incarnate by the Holy Spirit and the Virgin Mary" and referred to the Holy Spirit as "the Lord and life-giver, Who proceeds from the Father, Who is worshiped and glorified together with the Father and the Son, Who has spoke through the prophets" (Leith, p.33). While the spirit is still seen as the life-giver, the main accent is on soteriology, an emphasis that intensified in the Reformation. From that time until the twentieth century, little reflection has been given to the spirit's activity in the world.

Two well-known twentieth-century theologians who have articulated a doctrine of the Holy Spirit in relation to contemporary science are the French Jesuit Pierre Teilhard de Chardin (1881-1955) and Wolfhart Pannenberg (1928–). In *The Divine Milieu* (1960), Teilhard clarified his evolutionary concept of life: "The same beam of light which christian spirituality, rightly and fully understood, directs upon the Cross to humanize it (without veiling it) is reflected on matter so as to spiritualize it" (p. 105). Matter generally drifts toward spirit, and one day "the whole divinizible substance of matter will have passed into the souls of men; all the chosen dynamisms will have been recovered; and then our world will be ready for the Parousia" (p. 110). The goal of the creative process is the spiritualization and divinization of all matter and its reception into the *christosphere*. According to Teilhard, the spirit is not independent of matter but elevates and moves it toward God.

Wolfhart Pannenberg regards the spirit "as the marvelous depth of life out of which all life originates" (1973, p. 106). Pannenberg understands the spirit as active in the self-transcendence of life, and he has used the field theories developed by Michael Faraday (1791–1867) and his successors to understand the spirit's activity in the world. According to Pannenberg, these field theories "claim a priority of the whole over the parts. This is of theological significance because God has to be conceived as the unifying ground of the whole universe if God is to be conceived as creator and redeemer of the world. The field concept could be used in theology to make the effective presence of God in every single phenomenon intelligible" (1988, p. 12).

Pannenberg sees the Stoic doctrine of the divine *pneuma* as a direct predecessor of the field theory that "was conceived as a most subtle matter which penetrates everything and holds the cosmos together by the powerful tension between its different parts, thus accounting for their cohesiveness as well as for the different movements and qualities of things" (1988, p. 13). Just as patristic theology rejected the Stoic notion that *pneuma* is a material element, modern field theorists, such as Albert Einstein in his first paper on special relativity of 1905, rejected ether, a hypothetical substance, as being necessary for the expansion of electromagnetic waves within the field. However, since the 1970s, quantum field theory of the vacuum has once again raised the idea of an ether, as has string theory.

Pannenberg contends that "since the field concept as such corresponds to the old concept of *pneuma* and was derived from it in the history of thought, theologians should also consider it obvious to relate the field concept of modern physics to the Christian doctrine of the dynamic presence of the divine Spirit in all of creation" (1988, p. 13). Field theory becomes Pannenberg's paradigm to show God's activity through the Holy Spirit. Pannenberg knows that there is a difference between how physics and theology perceive the world. Nevertheless he develops the doctrine of the Holy Spirit using field theory, although neither God nor the Holy Spirit can be conceived as a field in any sense known to physics. Here Pannenberg has been strongly challenged. It remains interesting that modern physics reflects what the Old Testament asserted in speaking of the *ruah* (spirit) of Yahweh.

See also CHRISTIANITY; FIELD THEORIES; PNEUMATOLOGY; SPIRIT

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HANS SCHWARZ

HOPE

The word *hope* refers to a concept, emotion, attitude of mind, and object of expectation that is expressed in different ways in different cultures. Its meaning develops in association with other notions, as in the cluster of faith, hope, and love. It may be focused on one central object—hope in God, or much less definite—sometimes people may half-hope for things. Such reflection is a human activity; rabbits do not reflect much on what they will do when they retire.

In order to survey the shape of hope an element of systematization is necessary. This will be invariably selective. Surveys of the Christian doctrine of hope have to try to avoid finding harmony in a tradition where there are significant elements of dissonance. There is a risk of assimilating too easily notions of hope in non-Christian sources with Christian paradigms. Linguistic usage, even in distinctive discourses, is rarely monolithic. Generalizations about the Greek view of hope, or whatever, are liable to be limited in their usefulness, and may easily obscure the balance of overlap and diversity in particular usage.

Reflections on hope

With these reservations, the tradition of theological reflection on hope may be instructive. Reflection upon possible futures, in optimistic anticipation, in trepidation, in trust, in resignation, does not always occur in a religious context. But it is an activity described and assessed as centrally important in major world religions. God is the source and the object of hope, of a positive future for the created order. Prophets are seen as sources of hope. Their return in various forms is anticipated as the expected fulfilment of hope. Transformation of the present world order, of the religious community, and of the self, as a physical or spiritual entity or both, as part of this process, is the content of hope. How this transformation is to be achieved is differently envisaged, from the cave paintings of Neolithic times to modern images of virtual reality. Hope is the antidote to despair, a widespread and damaging aspect of human life. The transformation may be encouraged by appropriately empathic human activity, from human sacrifice to psychotherapy.

The ancient Mediterranean world produced a huge variety of reflection on hope, sacred and secular, from the Greek poet Pindar (c. 520–438 B.C.E.) to Roman statesman and orator Cicero (106–43 B.C.E.) and beyond through the Church Fathers. These variations were accessibly documented by Rudolf Bultmann (1884–1976) in his standard article on hope in Gerhard Kittel's *Theological Dictionary of the New Testament,* which emphasized the different usages, and in Geoffrey Lampe's *A Patristic Greek Lexicon* (1961). Drawing on an early monograph by Hans Georg Gadamer (1900–2002), Bultmann illustrated from Plato the twin aspects of objective hope and subjective expectation in human reflection on existence, reflection that is essential to give people something to live for. Hope is associated with love, for it is drawn towards the good and the beautiful. In a religious context, as in the Mysteries, hope may be sustained by the promise of eternal life. Plato was aware that hope may be dangerous and deceptive. Hence perhaps the turn by the Stoic philosophers to an avoidance of hope—if one does not hope for too much, one will not suffer disappointment.

Hope in the Hebrew Bible and, following this tradition, in the New Testament is centered upon God and the promise of God for the future of the people of God. In the Psalms a secure hope is based on God; any other basis is a false security. In the New Testament, especially in the Pauline writings, there is patient trust in God, in the expectation of the unfolding of God's future. In 1 Corinthians 13 hope is bound up with faith and love. The resurrection of Jesus Christ becomes the cornerstone of hope. The New Testament is everywhere colored by the overarching hope in eschatological expectation of the coming of the Kingdom. This foundation of hope on the presence of God—past, present, and to come—is taken up in the Fathers and in the theologies of the medieval, Reformation, and modern periods, reshaped according to the cultural imagination of the period (classically in the tradition of the three theological virtues of faith, hope, and love). Augustine of Hippo (354–430 C.E.) reflects the dialectic between hope and memory. For Thomas Aquinas (c. 1225–1274), hope is not simply the fruit of experience but hope in God is a learned habit of will. Not to hope is sinful. Martin Luther (1483–1546) and John Calvin (1509–1564) both interpret the gospel as promise, though this promise is of course firmly based on past and present action by God.

Notions of eschatological hope tended to be replaced in modern Western thought by ideas of progress and evolution. There is a unique amalgam of eschatological hope, apocalyptic imagery, and Enlightenment progress in Karl Marx (1818–1883) whose work was classically taken up by the mid-twentieth century philosopher Ernst Bloch in his massive *The Principle of Hope* (1952–1959). Bloch in turn famously inspired Jürgen Moltmann to write his *Theology of Hope* (1964), which sparked off a rediscovery of the importance of hope and a reorientation towards the future in theology. The turn to eschatology, and the thought of the determination of the present by the future, continues to be developed by Wolfhart Pannenberg and others.

For Luther hope was basically individual hope. Moltmann stressed the social and political dimensions, providing an important stimulus for a theology of liberation or emancipation, and for a new turn to the future as a focus for theology. This continues to be developed as a liberation of the oppressed through the freedom of the gospel, and through black, gay, feminist, and other theologies. A theology of the Holy Spirit understands the future as a future of Christlikeness.

Science and the theology of hope

What does theology of hope have to do with the dialogue between science and religion? Hope has objective as well as subjective dimensions. The future of the physical universe is certainly relevant to one strand of the complex thread of Christian hope. Exploration of divine action in relation to human life, through the natural sciences from cosmology to neuroscience, is seminal to grounds for hope. Hope is more than wishful thinking or blind optimism despite unpleasant facts. It is the hope of love, of corporate participation in the life of God.

A great deal of Christian theology has been devoted to engagement with the past and with the sense of tradition. Doctrines of creation have been especially past-oriented. Faith believes that the future of tradition may be much longer, and much more exciting, than its past. Creation points forward to new creation, to the unfolding of the divine purpose for the cosmos. Here the concept of hope is central. The future is not to be feared, for it is God's future. This is in turn a challenge to be open to new ideas and ready to revise existing paradigms. Hope suggests humility in the face of an unfolding mystery, an openness to surprise, and willingness to accept risk. Hope rests on the past fulfilment of God's promise for humanity and is resolved to look forward with confidence.

See also ESCHATOLOGY; HOLY SPIRIT; LIBERATION; LIBERATION THEOLOGY; PLATO; PROGRESS; THOMAS AQUINAS

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GEORGE NEWLANDS

HUMAN ECOLOGY

Human ecology is the interaction between humans and their environment, particularly the living ecosystems on which human life depends. An *ecosystem* is all the living organisms in a habitat, such as the fish and algae in a pond or the trees and earthworms in a forest, and the physical factors that support and affect them, such as sunlight and precipitation. Humans collect or grow food and fuel resources from Earth's ecosystems and are part of the Earth's food chains, where plants fix energy via photosynthesis, then animal herbivores consume the plants, and animal predators consume the herbivores. In the wake of global industrialization and a great increase in human population size, people are having an ever greater impact on the function and structure of the Earth's ecosystems. Humans are clearing much of the world's forest land, damming many of the world's rivers, and managing a majority of the Earth's most productive soils for agriculture.

Although science and engineering can develop new technologies that damage the environment, scientific research can conversely provide new environmentally friendly technologies for controlling pollution, collecting energy, and improving crop yields. Scientists studying ecosystems guide human interactions with the environment by documenting and monitoring human-initiated disturbances that result from, for example, the harvesting of timber, the catching of fish, or the building of cities, and they test new methods of restoring damaged ecosystems.

The world's religions also encourage human respect and care for ecosystems by providing explanations for natural phenomena and by discouraging destructive human activities and attitudes. The myths of Pacific Northwest Indians, for example, describe the cycle of salmon returning from the sea to spawn in rivers. The First Fish ceremony, held at the beginning of the salmon runs, temporarily halts all salmon harvest, thereby allowing some fish to escape and lay their eggs. Religious rituals or teachings can guide planting times and soil-conserving fallow on farm fields. Some Christian and Jewish farmers follow biblical instructions to provide a Sabbath year for the land to allow the soil to recover from crops. Islamic law provides guidance in managing wells, irrigation, and grazing lands. Religion may also protect the environment by discouraging greed and waste, and by encouraging respect for all creatures. The Jewish law found in the Torah, for example, prohibits wanton destruction of natural features, such as trees. Buddhists carefully replace insects and worms disturbed by plowing agricultural fields.

Religions may also designate ecosystems or species as sacred or provide them with special status, thus reducing over-harvest and conserving ecosystem components, such as predators. Native Hawaiian religion, for example, identifies some large sharks as family deities, thereby prohibiting their capture. Australian aborigines learn to respect plants and animals by adopting them as clan totems. Christian Ethiopian monks allow wildlife to remain undisturbed on their monastic grounds. Many religions identify scared trees or groves that may not be cut, or holy springs or rivers that may not be polluted.

Although they are frequently portrayed as opposites, both science and religion guide human environmental decision-making by identifying the best management alternatives, and encouraging human respect for, care of, and right relationship with the Earth's ecosystems.

See also BIOLOGICAL DIVERSITY; CHRISTIANITY, HISTORY OF SCIENCE AND RELIGION; ECOFEMINISM; ECOLOGY, ETHICS OF; ECOLOGY, RELIGIOUS AND PHILOSOPHICAL ASPECTS; ECOLOGY, SCIENCE OF; ECOTHEOLOGY; ISLAM, CONTEMPORARY ISSUES IN SCIENCE AND RELIGION; JUDAISM, CONTEMPORARY ISSUES IN SCIENCE AND RELIGION

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SUSAN POWERS BRATTON

HUMAN GENOME PROJECT

The worldwide effort, originally named the *Human Genome Initiative* but later known as the *Human Genome Project* or HGP, began in 1987 and was celebrated as complete in 2001. When begun, HGP was dubbed "big science" comparable to placing human beings on the moon. It was international in scope, involving numerous laboratories and associations of scientists around the world and receiving public funding in the United States of $200 million per year with a scheduled fifteen year timeline. The U.S. Department of Energy (DOE) began funding the project in 1987, followed by the National Institutes of Health (NIH) in 1990.

History and goals

The scientific goal was to map the genes and sequence human DNA. Mapping would eventually reveal the position and spacing of the then predicted one hundred thousand genes in each of the human body's cells; sequencing would determine the order of the four base pairs—the *A* (adenine), *T* (thymine), *G* (guanine), and *C* (cytosine) nucleotides—that compose the DNA molecule. The primary motive was that which drives all basic science, namely, the need to know. The secondary motive was perhaps even more important, namely, to identify the four thousand or so genes that were suspected to be responsible for inherited diseases and prepare the way for treatment through genetic therapy. This would benefit society, HGP architects thought, because a library of DNA knowledge would jump start medical research on many fronts. Many early prophecies found their fulfillment. Some did not.

What was not anticipated was the competition between the private sector and the public sector. J.

Craig Venter (b. 1946) led the private sector effort. While on a grant from NIH, Venter applied for nearly three thousand patents on Expressed Sequence Tags (ESTs). The ESTs located genes but stopped short of identifying gene function. A furor developed when researchers working with government money applied for patents on data that merely reports knowledge of what already exists in nature—knowledge of existing DNA sequences—and this led to the 1992 resignation of James Watson (b. 1928) from the directorship of NIH's National Center for Human Genome Research (NCHGR). Watson, who along with Francis Crick (b. 1916) is famed for his discovery of the double helix structure of DNA, was the first to head the NCHGR

Venter then established The Institute for Genomic Research (TIGR) and began using Applied Biosystems automatic sequencers twenty-four hours per day to speed up nucleotide sequencing and the locating of ESTs. By 1998 Venter had established Celera Genomics with sequencing capacity fifty times greater than TIGR, and by June 17, 2000, he concluded a ninety percent complete account of the human genome. It was published in the February 16, 2001, issue of *Science.*

Francis Collins (b. 1950) took over NCHGR leadership from Watson and found himself driving the public sector effort, racing with Venter toward the mapping finish line. Collins drew twenty laboratories worldwide with hundreds of researchers into the International Human Genome Sequencing Consortium, which he directed from his Washington office. Collins repudiated patenting of raw genomic data and sought to place DNA data into the public domain as rapidly as possible so as to prevent private patenting. His philosophy was that the human genome is the common property of the whole human race. The public project finished almost simultaneously with the private, and the ninety percent complete Collins map appeared one day prior to Venter's on February 15, 2001, in *Nature.*

Human DNA, as it turns out, is largely junk—that is, 98.6 percent does not code for proteins. Half of the junk DNA consists of repeated sequences of various types, most of which are parasitic elements inherited from our distant evolutionary past. Only 1.1 percent to 1.4 percent constitute sequences that code for proteins that function as genes.

Of dramatic interest is the number of genes in the human genome. At the time of the announcement, Collins estimated there are 31,000 protein-encoding genes; he could actually list 22,000. Venter could provide a list of 26,000, to which he added an estimate of 10,000 additional possibilities. For round numbers, the estimate in 2001 stood at 30,000 human genes.

This is philosophically significant, because when the project began in 1987 the anticipated number of genes was 100,000. It was further assumed that human complexity was lodged in the number of genes: the greater the number of genes, the greater the complexity. So, confusion appeared when, nearing the completion of HGP, scientists could find only a third of the anticipated number. Confusion was enhanced when the human genome was compared to a yeast cell with 6,000 genes, a fly with 13,000 genes, a worm with 26,000 genes, and a rice cell with 50,000 genes. On the basis of the previous assumption, a grain of rice should be more complex than Albert Einstein.

With the near completion of HGP, no longer could human uniqueness, complexity, or even distinctiveness be lodged in the number of genes. Collins began to speculate that perhaps what is distinctively human could be found not in the genes themselves but in the multiple proteins and the complexity of protein production. Culturally, DNA began to lose some of its magic, some of its association with human essence.

The theology and ethics of HGP

At the outset, HGP scientists anticipated ethical and public policy concerns; they were acutely aware that their research would have an impact on society and were willing to share responsibility for it. When in 1987 James Watson counseled the U.S. Department of Health and Human Services to appropriate the funds for what would become HGP, he recommended that three percent of the budget be allotted to study the ethical, legal, and social implications of genome research. Watson insisted that society learn to use genetic information only in beneficial ways; if necessary, the government should pass laws at both the federal and state levels to prevent invasions of privacy and discrimination on genetic grounds. Moral controversy broke out repeatedly during the near decade and a half of research.

Religious responses to the advancing frontier of genetic knowledge emerge mainly from people's concern to relieve human suffering and employ science to improve human health and well-being. A statement prepared by the National Council of Churches under the leadership of Union Seminary ethicist Roger L. Shinn affirms that churches in the United States must be involved with genetic research and therapy. "The Christian churches understand themselves as communities dedicated to obeying the will of God through service to others. The churches have a particular concern for those who are hurt or whose faith has been shaken, as demonstrated by the long history of the churches in providing medical care .... Moreover, the churches have a mission to prevent suffering as well as to alleviate it."

In 1990 the Center for Theology and the Natural Sciences (CTNS) at the Graduate Theological Union (GTU) in Berkeley, California, obtained one of the first grants offered by the Ethical, Legal, and Social Issues (ELSI) division of NCHGR. A team of molecular biologists, behavioral geneticists, theologians, and bioethicists monitored the first years of HGP research to articulate theological and ethical implications of the new knowledge. Many religious and ethical issues eventually became public policy concerns. These are adumbrated below.

Genetic discrimination. When Watson recommended the establishment of ELSI, the first public policy concern was what he called *privacy,* here called *genetic discrimination.* An anticipated and feared scenario took the following steps. As researchers identify and locate most if not all genes in the human genome that either condition or, in some cases, cause disease, the foreknowledge of an individual's genetic predisposition to expensive diseases could lead to loss of medical insurance and perhaps loss of employment opportunities. As HGP progressed, the gene for cystic fibrosis was found on chromosome seven, and Huntington's chorea on chromosome four. Alzheimer's disease was sought on chromosome twenty-one, and colon cancer on chromosome two. Disposition to muscular dystrophy, sickle-cell anemia, Tay Sachs disease, certain cancers, and numerous other diseases turned out to have locatable genetic origins. More knowledge is yet to come. When it comes, it may be accompanied by an inexpensive method for testing the genome of each individual to see if he or she has any genes for any diseases. Screening for all genetic diseases may become routine for newborns just as testing for phenylketonuria (PKU) has been since the 1960s. A person's individual genome might become part of a data bank to which each person, as well as health care providers, would have future access. The advantage is clear: Medical care from birth to grave could be carefully planned to delay onset, appropriately treat, and perhaps even prevent or cure genetically-based diseases.

Despite the promise for advances in preventative health care, fear arises due to practices of commercial insurance. Insurance works by sharing risk. When risk is uncertain to all, then all can be asked to contribute equally to the insurance pool. Premiums can be equalized. Once the genetic disorders of individuals become known, however, this could justify higher premiums for those demonstrating greater risk. The greater the risk, the higher the premium. Insurance may even be denied those whose genes predict extended or expensive medical treatment.

Some ethicists are seeking protection from discrimination by invoking the principles of confidentiality and privacy. They argue that genetic testing should be voluntary and that the information contained in one's genome be controlled by the patient. This argument presumes that if information can be controlled, then the rights of the individual for employment, insurance, and medical care can be protected. There are grounds for thinking this approach will succeed. Title VII of the 1964 Civil Rights Act restricts pre-employment questioning about work-related health conditions. Paragraph 102.b.4 of the Act potentially protects coverage for the employee's spouse and children. Legislative proposals during the 1990s and early 2000s seem to favor privacy.

Other ethicists argue that privacy is a misguided cure for this problem. Privacy will fail, say its critics, because insurance carriers will press for legislation fairer to them, and eventually protection by privacy may slip. In addition, computer linkage makes it difficult to prevent the movement of data from hospital to insurance carrier and to anyone else bent on finding out. Most importantly, the privacy argument overlooks the principle that genome information should not finally be restricted. The more society knows, the better the health care planning can be. In the long run, what society needs is information without discrimination. The only way to obtain this is to restructure the employment-insurance-health care relationship. The current structure makes it profitable for employers and insurance carriers to discriminate against individuals with certain genetic configurations—that is, it is in their best financial interest to limit or even deny health care. A restructuring is called for so that it becomes profitable to deliver, not withhold, health care. To accomplish this the whole nation will have to become more egalitarian—that is, to think of the nation itself as a single community willing to care for its own constituents.

The Abortion controversy. Given the divisiveness of the abortion controversy in the United States and certain other countries, fears arise over possible genetic discrimination in the womb or even prior to the womb in the petri dish. Techniques have been developed to examine in vitro fertilized (IVF) eggs as early as the fourth cell division in order to identify so-called defective genes, such as the chromosomal structure of Down syndrome. Prospective parents may soon routinely fertilize a dozen or so eggs in the laboratory, screen for the preferred genetic make up, implant the desired zygote or zygotes, and discard the rest. What will be the status of the discarded embryos? Might they be considered abortions? By what criteria does one define "defective" when considering the future of a human being? Should prospective parents limit themselves to eliminating "defective" children, or should they go on to screen for enhancing genetic traits such as blue eyes or higher intelligence? If so, might this lead to a new form of eugenics, to selective breeding based upon personal preference and prevailing social values? What will become of human dignity in all this?

Relevant here is that the legal precedent set by *Roe v. Wade* (1973) would not serve to legitimate discarding preimplanted embryos. This Supreme Court case legalized the use of abortion to eliminate a fetus from a woman's body as an extension of a woman's right to determine what happens to her body. This would not apply to preimplanted embryos, however, because they are life forms outside the woman's body.

The Roman Catholic tradition has set strong precedents regarding the practice of abortion. The Second Vatican Council document *Gaudium et spes* (1965) states the position still held today: "… from the moment of its conception life must be guarded with the greatest care, while abortion and infanticide are unspeakable crimes." The challenge to ethicists in the Roman Catholic tradition in the near future will be to examine what transpires at the preimplantation stage of the embryo to determine if the word *abortion* applies. If it does, this may lead to recommending that genetic screening be pushed back one step further, to the gamete stage prior to fertilization. The genetic make up of sperm and ovum separately could be screened, using acceptable gametes and discarding the unacceptable. The Catholic Health Association of the United States pushes back still further by recommending the development of techniques of gonadal cell therapy to make genetic corrections in the reproductive tissues of prospective parents long before conception takes place—that is, gametocyte therapy.

Genetic determinism, human freedom, and the gene myth. Religious thinkers must deal not only with laboratory science but with the cultural interpretations of science, as well as public policy influenced by both. A cultural myth has grown up with media coverage of the Human Genome Project that assumes "it's all in the genes." DNA has emerged as a cultural icon, holding the "blueprint" for humanity or being thought of as the "essence" of what makes a person a person. Even though molecular biologists withdraw from such extreme forms of genetic determinism, a cultural myth has arisen. Some commentators refer to it as the *strong genetic principle*; others call it the *gene myth*.

Genes, sin, crime, and racial discrimination. The belief in determinism promulgated by the gene myth raises the question of moral and legal culpability. Does a genetic disposition to antisocial behavior make a person guilty or innocent before the law? Over the next decade legal systems will have to face a rethinking of the philosophical planks on which concepts such as free will, guilt, innocence, and mitigating factors have been constructed. There is no question that research into the connection between genetic determinism and human behavior will continue and new discoveries will become immediately relevant to the prosecution and defense of those accused of crimes. The focus will be on the concept of free will, because the assumption of the Western philosophy coming down from Augustine that underlies understanding of law is that guilt can only be assigned to a human agent acting freely. The specter on the genetic horizon is that confirmable genetic dispositions to certain forms of behavior will constitute compulsion, and this will place a fork in the legal road: Either the courts declare the person with a genetic disposition to crime to be innocent and set him or her free, or the courts declare him or her so constitutionally impaired as to justify incarceration and isolation from the rest of society. The first fork would jeopardize the welfare of society; the second fork would violate individual rights.

That society needs to be protected from criminal behavior, and that such protection could be had by isolating individuals with certain genetic dispositions, leads to further questions regarding insanity and race. The issue of insanity arises because the genetic defense may rely upon precedents set by the insanity defense. The courts treat insanity with a focus on the insane person's inability to distinguish right from wrong when committing a crime. When a defendant is judged innocent on these grounds, he or she is incarcerated in a mental hospital until the medical evaluators judge that the individual is cured. Once cured, the person may be released. In principle, such a person might never be judged "cured" and may spend more time in isolation than the prison penalty prescribed for the crime, maybe even the rest of his or her life. Should the genetic defense tie itself to the insanity defense, and if one's DNA is thought to last a lifetime, then the trip to the hospital may become the equivalent of a life sentence. In this way the genetic defense may backfire.

With this prospect, we have returned to the specter of genetic discrimination. The current discussion of possible genetic influence on antisocial behavior is riddled with fears of discrimination, especially its racial overtones. Because the percentage of black men among the population of incarcerated prisoners is growing, society could invoke the gene myth to associate genes with criminal predispositions and with race. A stigma against black people could arise, a presumption that they are genetically predisposed to crime. University of California sociologist Troy Duster fears that if we identify crime with genes and then genes with race, we may inadvertently provide a biological support for prejudice and discrimination.

The gay gene. Theological and ethical debate has arisen over the 1993 discovery of a possible genetic disposition to male homosexuality. Dean H. Hamer and his research team at the U.S. National Cancer Institute announced that they discovered evidence that male homosexuality—at least some male homosexuality—is genetic. Constructing family trees in instances where two or more brothers are gay combined with actual laboratory testing of homosexual DNA, Hamer located a region near the end of the long arm of the X chromosome that likely contains a gene influencing sexual orientation. Because men receive an X chromosome from their mother and a Y from their father (women receive two X's, one from each parent), this means that the possible gay gene is inherited maternally. Mothers can pass on the gay gene without themselves or their daughters being homosexual. A parallel study of lesbian genetics is as yet incomplete; and the present study of gay men will certainly require replication and confirmation. Scientists do not yet have indisputable proof.

The ethical implications, should a biological basis for homosexuality be confirmed, could point in more than one direction. The scientific fact does not itself determine the direction of the ethical interpretation of that fact. The central ethical question is this: Does the genetic disposition toward homosexuality make the bearer of that gene innocent or guilty? Two answers are logically possible.

On the one hand, a homosexual man could claim that because he inherited the gay gene and did not choose a gay orientation by his own free will, he is innocent. The biological innocence position could be buttressed by an additional argument that homosexual activity is not itself sinful; it is simply one natural form of sexual expression among others. One could go still further to say that because it is biologically inherited that it is God's will; that a person's homosexual predisposition is God's gift.

On the other hand, one could follow the opposite road and identify the gay gene with a carnal disposition to sin. Society could claim that the body inherited by each person belongs to who they are—people are determined at least in part by what their parents bequeathed them—and that an inherited disposition to homosexual behavior is just like other innate dispositions such as lust or greed, which are shared with the human race generally; all this constitutes the state of original sin into which we are born. Signposts point in both ethical directions.

Beyond the question of guilt or innocence ethicists anticipate another issue, namely, the risk of stigma. Might the presence of the gay gene in an unborn fetus be considered a genetic defect and become grounds for abortion? Would routine genetic testing lead to a wholesale reduction of gay men in a manner parallel to that of children with Down Syndrome? Would this count as class discrimination?

Somatic therapy versus germline enhancement. The debate over two distinctions—somatic versus germline intervention and therapy versus enhancement intervention—involves both secular and religious discussions. The term *somatic therapy* refers to the treatment of a disease in the body cells of a living individual by trying to repair an existing defect. The term *germline therapy* refers to intervention into the gametes, perhaps for the purpose of eliminating a gene such as that for cystic fibrosis so that it would not be passed along to future generations. Both somatic and germline therapies are conservative when compared to genetic enhancement. Enhancement goes beyond mere therapy for existing genes that may be a threat to health by selecting or adding genes to make an individual "superior" in some fashion. Enhancement might involve genetic engineering to increase bodily strength or intelligence or other socially desirable characteristics.

Ethical commentators almost universally agree that somatic therapy is morally desirable, and they look forward to the advances HGP will bring for expanding this important work. Yet they stop short of endorsing genetic selection and manipulation for the purposes of enhancing the quality of biological life for otherwise normal individuals or for the human race as a whole. New knowledge gained from HGP might locate genes that affect the brain's organization and structure so that careful engineering might lead to enhanced ability for abstract thinking or to other forms of physiological and mental improvement.

Religious ethicists argue that somatic therapy should be pursued, but enhancement through germline engineering raises cautions about protecting human dignity. In a 1982 study, the World Council of Churches stated: "Somatic cell therapy may provide a good; however, other issues are raised if it also brings about a change in germline cells. The introduction of genes into the germline is a permanent alteration .... Nonetheless, changes in genes that avoid the occurrence of disease are not necessarily made illicit merely because those changes also alter the genetic inheritance of future generations .... There is no absolute distinction between eliminating defects and improving heredity" (quoted in Peters, ed., 1998, pp. 6–8). The primary caution raised by the WCC here has to do with the lack of knowledge regarding the possible consequences of altering the human germline. The present generation lacks sufficient information regarding the long term consequences of a decision today that might turn out to be irreversible tomorrow. Thus, the WCC does not forbid forever germline therapy or even enhancement; rather, it cautions people to wait and see.

The Catholic Health Association is more positive: "Germline intervention is potentially the only means of treating genetic diseases that do their damage early in embryonic development, for which somatic cell therapy would be ineffective. Although still a long way off, developments in molecular genetics suggest that this is a goal toward which biomedicine could reasonably devote its efforts" (p. 19)

Another reason for caution regarding germline enhancement, especially among the Protestants, is the specter of eugenics. The word *eugenics* connotes the ghastly racial policies of Nazism, and this accounts for much of today's mistrust of genetic science in Germany and elsewhere. No one expects a resurrection of the Nazi nightmare; yet some critics fear a subtle form of eugenics slipping in the cultural back door. The growing power to control the design of living tissue will foster the emergence of the image of the "perfect child," and a new social value of perfection will begin to oppress all those who fall short.

Gene patenting. A controversy exploded in 1991 over gene patenting prompted by the filing for intellectual property rights by J. Craig Venter on nearly three thousand ESTs, expressed sequence tags. Each of these ESTs consisted of three hundred to five hundred base pairs made from cDNAs, copies of DNA sequences produced by polymerase chain reaction. ESTs are gene fragments, not whole genes; hence they mark the location of a gene but cannot identify gene function. Two issues became the focus of controversy. First, should the U.S. Patent and Trademark Office grant patents on genomic data? Even though the patents applied for were on copies of DNA sequences, their only value was to report raw genomic information. It appeared to critics that these applications failed to meet the three patenting criteria: novelty, utility, and nonobviousness. Second, should the U.S. government apply for and receive such patents in competition with the private sector? Venter's first patent applications were filed while he was working on a government grant; later he moved to the private sector and continued filing for intellectual property rights on his discoveries. James Watson followed by Francis Collins at the NIH both opposed patenting raw genomic data.

Cloning. Technically known as "somatic cell nuclear transfer," cloning techniques were developed in 1996 by Ian Wilmut at the Roslin Institute near Edinburgh, Scotland. Wilmut announced the cloning of Dolly the sheep in February 1997. The scientific breakthrough consisted of returning an already differentiated DNA nucleus to its pre-differentiated state and then transferring it to an enucleated oocyte to make an embryo. The new embryo thus contains the genome of the donor nucleus. In the worldwide controversy that broke out in 1997 and continues in bioethical discussion, the debate seems to bypass the science of nuclear transfer; rather, the focus is on producing multiple human beings with duplicate genomes. Critics of reproductive cloning argue that children produced by cloning would suffer from loss of individuality, identity, and dignity. Roman Catholic critics along with Wilmut himself oppose human reproductive cloning on the grounds of safety—that is, the imperfect technology would lead to the destruction of many early embryos. Defenders of nuclear transfer research distinguish sharply between reproductive cloning, which they oppose, and therapeutic cloning, which is necessary for stem cell research.

Stem cells. The isolation of human embryonic stem cells (hES cells) was accomplished in August 1997 by James Thomson at the University of Wisconsin on funds from the Geron Corporation. The hES cells are removed from the inner mass of the blastocyst, an embryo at four to six days old. When isolated and placed on a feeder tray, hES cells become immortal—that is, they divide indefinitely. In addition, they are pluripotent and able to differentiate into any and every tissue. The research goal is to control gene expression so as to make designated tissue for rejuvenating human organs. Some progress in gene control has been achieved. The next hurdle to jump is histocompatibility, namely, to avoid organ rejection by matching donor and recipient genetic codes. It is likely that experiments with somatic cell nuclear transfer will be required to attain histocompatibility. Ethical objections to stem cell research from Roman Catholics center on destruction of blastocysts for research purposes. Ethical support for stem cell research stresses beneficence; it emphasizes the marvelous advances in human health and well-being that this medical science might offer the human race.

Conclusion: theological commitments to human dignity

Virtually all Roman Catholics and Protestants who take up the challenge of the new genetic knowledge seem to agree on a handful of theological axioms. First, they affirm that God is the creator of the world and, further, that God's creative work is ongoing. God continues to create in and through natural genetic selection and even through human intervention in the natural processes. Second, the human race is created in God's image. In this context, the divine image in humanity is tied to creativity. God creates; so do human beings. With increasing frequency, humans are described by theologians as *co-creators* with God, making their human contribution to the evolutionary process. In order to avoid the arrogance of thinking that humans are equal to the God who created them in the first place, people must add the term *created* to make the phrase *created co-creators*. This emphasizes human dependency on God while pointing to human opportunity and responsibility. Third, these religious documents place a high value on human dignity.

By *dignity* they mean what eighteenth-century German philosopher Immanuel Kant meant, namely, that each human being is treated as an end, not merely as a means to some further end. As church leaders respond responsibly to new developments in HGP, one thing can be confidently forecast: This affirmation of dignity will become decisive for thinking through the ethical implications of genetic engineering. Promoting dignity is a way of drawing an ethical implication from what the theologian can safely say, namely, that God loves each human being regardless of his or her genetic makeup and, therefore, people should love one another according to this model.

See also BEHAVIORAL GENETICS; BIOTECHNOLOGY; CLONING; DNA; EUGENICS; FREEDOM; GENE PATENTING; GENE THERAPY; GENETIC DETERMINISM; GENETIC ENGINEERING; GENETICS; GENETIC TESTING; NATURE VERSUS NURTURE; PLAYING GOD; SIN; SOCIOBIOLOGY; STEM CELL RESEARCH

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TED PETERS

HUMANISM

The term *humanism* over the past several centuries of Western thought has been used to express two different concepts. It is not too much to say that humanism in its original form created the intellectual foundation of the Renaissance. In modern times, humanism has most often come to mean an approach that characterizes all things in a human, rather than theistic, framework and emphasizes human rationality and experience in contrast to classic authority. It is arguable, however, that the adversarial relationship between theism and the human, including scientific knowledge and rationality, that is often imputed to modern humanism is unnecessarily simplistic, ignoring, for example, today's Christian humanists. Moreover, it is possible to detect the evolution of a new, more integrative, humanism as a response to a world whose natural cycles and processes are increasingly dominated by the human.

Humanism in its original sense meant simply the rediscovery and study of classic Greek and Latin language and texts, and the use of them to assess the work of doctrinal Scholastics and secondary commentaries of late Medieval Europe. Humanism during this time was more a cultural attitude and an academic program than a formal conceptual framework or a particular philosophy. Indeed, the first self-conscious humanist, the Italian poet Francis Petrarch (1304–1374), is notable for urging a new curricula based on original classical sources—the *studia humanitatis,* consisting of grammar, rhetoric, poetry, history, and moral philosophy. During this period, the term *humanist* had no ideological content and simply referred to anyone, layperson or Church official, who had a competence in classical Greek, Latin, and to a lesser extent Hebrew, and some familiarity with classical texts.

Early humanism led to the recovery of the direct study of the Bible. Many early medieval Church figures such as Thomas More (1478–1535) and Desiderius Erasmus (1469–1536), and a number of reformers, strongly supported the humanist approach. In general, however, early humanism was stronger in Italy than in the more medieval north of Europe. Thus, Pope Nicholas V (1447–1455) is referred to by Bertrand Russell in *A History of Western Philosophy* (1945) as "the first humanist Pope" (p. 498). Nicholas's apostolic secretary was the epicurean humanist Lorenzo Valla (1407–1457). Reflecting their culture, the vast majority of humanists were practicing Christians, although they tended to react against the medieval Scholastic veneration of authority. Valla, for example, wrote a long treatise somewhat inelegantly titled *Restructuring of All Dialectic with the Foundations of the Whole of Philosophy,* in which he purported to demonstrate the invalidity of Aristotelian logic, a foundation of Scholasticism.

As Western culture evolved, however, humanism inevitably began to challenge medieval worldviews in fundamental ways. Rather than the authority of Aristotle (384–322 B.C.E.), Augustine of Hippo (354–430), and Thomas Aquinas (c. 1225–1274), humanists rediscovered and began to teach classical texts of all types. These not only greatly broadened the knowledge base available to scholars and the educated, but stimulated both increased curiosity about the world in general and a different concept of validity. During the early medieval period, reference to accepted authority was the highest demonstration of truth; humanism over time led to increased reference to the physical world as the ultimate source of validity in argument. The authority of Galen (c. 130–201 C.E.) in medicine or Aristotle in physics was increasingly challenged by data and argument derived not from accepted texts but from observation of the world itself. In doing so, humanism created the foundations for the profound ontological shift from the otherworldliness of medieval faith to scientific knowledge that characterized the Enlightenment and, subsequently, modernity.

The Enlightenment is often characterized as a conflict between faith and reason, but that is misleading. Major Enlightenment figures, including on the nascent rationalist side Francis Bacon (1561–1626) and, later, Isaac Newton (1642–1727), clearly viewed their scientific work as aligned with the Christian faith, even mandated by it. On the literary side, the Romantic project was seen by many of its leading figures as an effort to modernize and humanize Christian theology in light of Enlightenment science, which had come to represent an independent and in some ways equally powerful ontology. Thus, the poet John Keats (1795–1821) saw his goal as creating "a system of Salvation which does not affront our reason and humanity" (quoted in Abrams, p. 33), a goal that can be broadly attributed to the Romantic movement in general.

Attitudes toward modern humanism mirror the distortions of the Enlightenment characterization.

In particular, the attacks by Christian fundamentalists on "secular humanism" in the United States, especially regarding the teaching of evolution, have created an impression that humanism is necessarily opposed to religion. Secular humanism, a tradition flowing from eighteenth-century Enlightenment rationalism and subsequent freethinking movements, is indeed characterized by a Promethean suspicion of theism and religious authority, and a belief that humans are the measure of all things; it is, however, but one branch of the humanist project. Modern humanists fall into many categories, including *literary humanism,* characterized by a devotion to the humanities; *cultural humanism,* the rational, empirical tradition derived from ancient Greece and Rome that forms the basis of modern Western societies; and *philosophic humanism,* systems of thought focused on human needs and realities.

Of particular interest, however, are the schools of humanism that explicitly integrate religious and scientific worldviews. Thus, Christian humanism, the philosophy that posits the self-fulfillment of humans within the framework of Christian principles and beliefs, has evolved from More and Erasmus through elements of the Anglican and German pietist traditions and philosophers such as Immanuel Kant (1724–1804). It is represented by modern theologians such as Jacques Maritain, Hans Küng, Paul Tillich, and James Luther Adams. More explicitly, the Unitarian Universalist tradition includes among its seven Principles three that are obviously humanist; they affirm (1) the "inherent worth and dignity of every person," (2) justice, "equity and compassion in human relations," and (3) a "free and responsible search for truth and meaning." The Unitarian Universalists also identify as among the sources of their tradition humanist "teachings which counsel us to heed the guidance of reason and the results of science, and warn us against idolatries of the mind and spirit."

This integration of faith and rationality will become increasingly important in light of the recognition that, as a result of the Industrial Revolution, population and economic growth, and globalization, the dynamics of most major natural systems are increasingly influenced by human activity. Since this results in a world where teleologies and belief systems are increasingly reified in natural systems through intentional human activity, a rational humanistic understanding, combined with the religious faith that is central to the human experience—perhaps an "Earth systems" humanism—may well be a future evolutionary path of humanism.

See also ARISTOTLE; AUGUSTINE; CHRISTIANITY; CREATIONISM; EVOLUTION; NEWTON, ISAAC; TELEOLOGY; THOMAS AQUINAS

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BRAD ALLEBY

HUMAN NATURE, PHYSICAL ASPECTS

A consideration of the physical aspects of human nature leads to viewing human nature as embodied. Embodiment as a concept is fluid, taking its forms from pathways of inquiry that inevitably remake it, however provisionally, according to the task at hand. But surely this is not true of the body. The body as a physical object, a thing, is solid. One points to it, sees its movement, hears the sounds it makes, feels its heart beating, smells its fragrance, and tastes its sharp salinity. Having a body is an undeniable fact of life, a solid place of unity between one human and another, even between human beings and the more than human world. But having a body may do no more to unify than would having a car, wearing clothes, having a mother, speaking English, and dying. Establishing links between the concepts of body and concepts such as human unity requires much more than the simple facts associated with being bodied. Apart from pathways of inquiry, then, the fact of body—its sensory undeniability—seems indeed solid, unmovable, a mountain of inertia.

So the challenge is to give a technical review that transforms some of this inertia into movements along paths of inquiry linking science and religion. Sadly, this requires that much that is wonderful about the body will be left out. Further, some scientific results summarized below (e.g., in relation to physical beauty, human emotion, etc.) may be susceptible to cultural context; most of the studies summarized in this entry relied on Western approaches to science and worked exclusively with subjects within Western cultures.

The major dynamical systems of the body

Human biology partitions the functions of the human body into eleven major dynamical systems: cardiovascular, endocrine, gastrointestinal, hematologic, integumentary, lymphatic, musculoskeletal, nervous, reproductive, respiratory, and urinary (Seeley, Stephens, and Tate, 1995).

The cardiovascular (or circulatory) system includes the structures of the heart, blood vessels, and blood. Its functions include the transport of oxygen and waste gases (e.g., carbon dioxide), nutrients, waste products, and hormones; the regulation of body temperature; the regulation of blood pressure; and a contribution to the immune response.

The endocrine system includes the structures of the pituitary, thyroid, parathyroid, thymus, and adrenal glands, as well as the pancreas, ovaries, and testis. Its major functions are the regulation of the following: metabolism and growth, the absorption of nutrients, fluid balance and ion (i.e., chemicals in the body with a positive or negative charge) concentration, the stress response, and sexual characteristics, reproduction, birth, and lactation.

The gastrointestinal system includes the oral cavity, salivary glands, esophagus, stomach, liver, gallbladder, small intestine, large intestine, and rectum. Its functions include the breakdown of food, the absorption of nutrients, and the elimination of wastes from the body.

The hematologic system includes blood plasma (91.5 percent water by volume), blood cells, red bone marrow, spleen, liver, and kidneys. Blood cells include erythrocytes (i.e., red blood cells) for the transport of oxygen and waste gases; neutrophils for consuming microorganisms and other substances in the blood (i.e., phagocytosis); basophils for the release of histamine in inflammatory responses and heparin to prevent blood clots; eosinophils for the reduction of inflammation and the attack of some worm parasites; lymphocytes for the production of antibodies and other substances to destroy microorganisms and other substances foreign to the body (e.g., transplanted organs); monocytes for the phagocytosis of bacteria, dead cells of the body, cell fragments, and other tissue debris; and platelets for clotting blood. Red bone marrow is the only source of blood formation in adults and occurs mainly in bones along the body's central axis and in the joints of limbs (i.e., epiphyses) that are closest to the center of the body. The spleen holds a reservoir of blood, which is released in emergencies. The kidneys release a chemical, erythropoietin, to stimulate erythrocyte production. Enlarged monocytes in the liver, called *macrophages,* consume old or defective erythrocytes. The liver also produces most of the body's clotting factors.

The integumentary system includes the structures of the skin, hair, nails, and sweat glands. It functions mainly to protect other areas of the body against abrasions and ultraviolet light, to prevent the entry of microorganisms and other harmful substances, to reduce water loss, to regulate body temperature, to produce precursors to vitamin D (increases calcium and phosphate uptake in the intestine), and to provide sensory information about the body and the body's environment.

The lymphatic, or immune, system includes lymph (a clear fluid that is returned to the blood via the lymphatic vessels; three liters per day), lymph vessels, lymph nodes, lymph ducts, the tonsils, spleen, thymus gland, and red bone marrow. The functions of the lymphatic system include removing foreign substances from the blood and lymph, defending the body against elements of disease, maintaining fluid balance in the tissues, and absorbing fat. The two major cell types in the lymphatic system are B cells, which mature to secrete antibodies, and T cells, which recognize foreign molecular patterns on the surface of the body's own cells. Once T cells identify something that is foreign to the body, they either kill the cell or they activate other immune responsive cells in the body (e.g., B cells, macrophages).

The musculoskeletal system includes the bones of the skeleton and all the muscles attached to the skeleton. Its main functions are to provide movement of the body, to maintain body posture, and to produce body heat. This system does not include the muscle of the heart or the smooth muscles that are not typically under voluntary control.

The nervous system includes the brain, the spinal cord, the nerves, and sensory receptors (e.g., photoreceptors in the eye). Its main functions are to provide sensory input for bodily action, to control bodily action (the somatic nervous system), to control physiological processes typically beyond voluntary control (the autonomic nervous system), and to allow for human experience.

The reproductive system in women includes the vagina, uterus, uterine tube, and ovary, and in men the penis, prostate, seminal vesicle, ductus (or vas) deferens, the testis, the epididymis, and scrotum. Its main functions are to assist in the control and performance of sexual behavior.

The respiratory system includes the nose, nasal cavity, pharynx, oral cavity, larynx trachea, bronchi, and lungs. Its major functions are to transport oxygen to the lungs, to exchange waste carbon dioxide for oxygen, and to regulate the acidity of the blood (i.e., blood pH).

The urinary system includes the kidneys, ureter, urinary bladder, and urethra. Its major functions are to remove wastes from the cardiovascular system; to regulate blood pH, ion balance and fluid balance; and to assist in regulating blood pressure.

Paleoanthropology, archaeology, and the body

Humanity's origin narratives within Western science depend largely on the bodily remains of humanity's ancestors. Where were the remains found? What is their three-dimensional character? How old are they? What damage have they sustained? According to Ann Gibbons in "In Search of the First Hominids" (2002), recent unearthings of ancient primate bones have generated controversies in human evolution on questions ranging from whether bipedalism evolved on the savannah to what makes a primate a hominid. Nicknames given to some of these recently uncovered remains, such as Flat-Faced Man and Little Foot, are consistent with the importance of the body in paleoanthropology.

Since the discovery of Lucy, then the earliest known hominid, in Ethiopia in 1973, early hominids have been defined by their bodily resemblance to Lucy. Lucy was small, about the size of a female chimpanzee, had long arms, a relatively small volume inside her skull (i.e., intracranial volume), thick tooth enamel, large molars, smaller canines than earlier paleoanthropological fossils, foot bones that suggested bipedalism, and curved fingers. However, there have also been attempts by scientists to classify hominids by one or a few bodily characteristics: *Ardipithecus ramidus* (Aramis, Ethiopia; 4.4 million years ago) because its canines are more like human canines than those of chimpanzees (the converse is true for its molars); *Ardipithecus ramidus kadabba* (Aramis, Ethiopia; 5.2 to 5.8 million years ago) because the bones of its feet suggest bipedalism; *Orrorin tugenensis* (Tugen Hills, Kenya; 5.7 to 5.9 million years ago) because its thighbone (i.e., femur) looks more like human femurs than do those of Lucy and other Australopithecines, it has even thicker tooth enamel than Ardipithecus, and it has molars more like human molars than those of chimpanzees (the converse is true for its canines).

Controversy is also present in identifying the number and nature of the evolutionary step(s) to *Homo sapiens* from its ancestor, due to the differences in scientific opinions as to which measurements of the body are the deciding ones. Daniel Lieberman has proposed replacing the typically long list of measurements used to classify hominid skulls with two: the roundness of the skull and the degree to which the face and eyes are tucked under the frontal bone (Balter, 2002). Reducing the number of measurements would, in Lieberman's view, reduce the complexity involving theories regarding the evolutionary appearance of *Homo sapiens*. Typically, however, measurements of human skulls (i.e., human craniometry) in paleoanthropology and archaeology involve over sixty different measures (Howells, 1989; White, 2000).

Beauty and the body

Bodily symmetry is generally the most consistent factor to correlate with assessments of physical beauty (Geary, 1998). Women prefer men with high bodily symmetry, a strong chin and cheekbones, and an emotionally expressive mouth. These preferences may have adaptive value in that illnesses during puberty are known to reduce the secretion of male hormones (i.e., androgens) which in turn decreases bone size and density (Thornhill and Gangstad, 1993). Additionally, lower facial symmetry in men correlates with higher baseline metabolism (Manning, Koukourakis, and Brodie, 1997) and higher incidents of depression, anxiety, and minor illnesses (Schakelford and Larsen, 1997). Note, however, that this correlation does not hold for individuals who are assessed as either very attractive or as unattractive (Kalick et al, 1998). Men's assessments of physical beauty in women also correlate with bodily symmetry but rely more on facial features showing youthfulness relative to a man's own age (Kenrick and Keefe, 1992), except during male adolescence (Kenrick et al, 1996). Finally, men think women with a waist-to-hip ratio of around 0.7 are more attractive than women with other ratios, and men find women of average weight with this ratio to be more attractive than heavier or thinner women who have this ratio (Geary, 1998). There is evidence suggesting that women with ratios larger than 0.85 become more ill and have a harder time conceiving children than women with ratios around 0.7 (Singh, 1995).

Smell also plays a role in assessing physical beauty. Evidence associates women's ratings of the bodily fragrances of men with differences between their *major histocompatibility complex* (MHC). Men who differ more in MHC from women raters are assessed as having more pleasant fragrances than men more similar to the women's MHC (Apanius et al, 1997). Having a more variable MHC is associated with greater flexibility in one's immune response, and thus this fragrance preference could reflect the effects of natural selection.

Self determination according to the immune system

The immune system provides for both innate immunity and adaptive immunity. Innate immunity applies to parts of the immune system that do not adapt within an individual organism to a particular immune challenge. Adaptive immunity includes those systems that adapt within an organism to respond in ways specific to each challenge event.

Innate immunity as an organismal function is evolutionarily old since its components are found in both plants and animals. Even single-celled organisms have the capacity to recognize "microbial nonself" (Medzhitov and Janeway, 2002). Genetic changes in the molecular structure of components of innate immunity (i.e., pattern recognition receptors, or PRRs) happen slowly via evolution (Janeway and Medzhitov, 2002). This in turn forces innate immunity to act only against those molecular patterns on nonself bodies (i.e., pathogen-associated molecular patterns, or PAMPs) that do not change rapidly across generations (i.e., antigens that are evolutionarily conserved). PRRs available in the blood or tissue fluid bind to PAMPs, providing a signal for pathogen destruction by cells such as macrophages or neutrophils or by complement. Complement is a group of proteins in blood plasma that undergo transition from inactive to active forms via action by PRRs and participate in the destruction of pathogens, largely by making a hole in the pathogenic cell (i.e., cell lysis). PRRs that are bound to cells are called *Toll-like receptors* (TLRs, because of similarities to immune-related proteins of the *Drosophila* Toll family). PRRs cannot differentiate between microorganisms that are pathogenic to the body and microorganisms that are beneficial to the body (e.g., those in the gustatory system) but are prevented from acting on beneficial microorganisms by physical barriers preventing their access.

Innate immunity also is responsible for what is called the recognition of *missing self* (Medzhitov and Janeway, 2002). The term *missing self* (instead of nonself) was chosen to highlight the observation that some components of innate immunity, instead of responding to molecular patterns of pathogens, respond to lower levels of molecular patterns specifically expressed by a body's own cells. This concept was introduced to account for observations that natural killer (NK) cells mainly kill tumor cells that lack MHC class I proteins. MHC class I proteins are adaptive immunity structures that can combine with parts of the body's own cells and are displayed on the surface of those cells to indicate the presence of a self cell. When cells in the body become cancerous, they display fewer or no MHC class I proteins bound with their own fragments. NK cells have proteins on their surfaces, called *receptors,* that recognize MHC class I proteins bound to self fragments and stop NK cells from killing (Medzhitov and Janeway, 2002). Other examples of innate immunity acting by recognizing a missing self include the activation mechanism of C3, a complement protein; the inhibition of macrophages and neutrophils through receptors on those cells that recognize sialic acid, which is expressed on vertebrate cells but generally not on microorganisms; and the inhibition of macrophages by the protein CD47, largely responsible for distinguishing between functioning and nonfunctioning erythrocytes. Note that these missing self strategies can be fooled if pathogens acquire the DNA that makes the self-specific molecules directly from the body's cells. Then they start looking like self according to the innate immune system. This is known to happen and is called *horizontal gene transfer.*

Adaptive immunity relies strongly on signals from the innate immune system. It is only present in jawed vertebrates, and its molecular components change in a challenge-specific manner. All jawed fish exhibit adaptive immunity, which is lacking in vertebrates without jaws, such as lampreys. Charles A. Janeway names this sudden appearance in the evolutionary record the "immunological 'Big Bang'" (Janeway et al, 2001, p. 602). In a series of experiments culminating in 1998, it was discovered that the genes mediating the genetic recombination underlying adaptive immunity could also mediate the insertion of one DNA fragment into others, a process known as *transposition* (Hiom, Melek, and Gellert, 1998; Agrawal, Eastman, and Schatz, 1998). Scientists infer from this result that adaptive immunity was acquired from a transposable element that inserted itself into the DNA of an ancestor of jawed vertebrates. Significantly, adaptive immunity, unlike innate immunity, is not hereditary. Genetic modifications that occur in adaptive immunity occur in somatic cells, not in the germline cells (sperm or eggs). This leads immunologists to say that the "memory" of adaptive immunity is limited to the lifespan of the individual, and immunizations must be repeated for each generation. Adaptive immunity is thought to contribute to greater lifespan, though it is the cause of rejection in organ transplantation.

Antibodies, or B-cell receptors, are a key component of molecular pattern recognition in the adaptive immune system. There are on the order of one hundred billion different antibody specificities in the human body (Janeway et al, 2001). The structure of an antibody molecule is modeled as a Y-shape. The stem of the Y is called the *constant region,* and the arms of the Y are called *variable regions.* There are five different classes of antibody: IgA, IgD, IgE, IgG, and IgM. IgG is the most abundant antibody class in humans. Each arm of an antibody's Y structure is composed of a heavy (H) chain and a light (L) chain. Moreover, each H and L chain in each arm of the Y is composed of a constant (C) and a variable (V) region, connected by a hinge.

Antibody diversity is produced in four major ways. The first two are controlled genetic recombination of gene segments forming the gene for the V-regions. Light chain V-region genes include the V gene segment (because it codes for most of the final V protein, 95 to 101 amino acids long) and the J gene segment (because it joins the V-region to the C-region, coding for up to thirteen amino acids). Heavy chain V-region genes include the V, J, and D (or diversity) gene segments. In addition to genetic recombination, diversity arises in different combinations of V and H chains at the protein level through different combinations of protein subunits. Finally, specialized mutations within B cells, occurring only at rearranged V-region DNA, add to the diverse antibody repertoire.

T-cell receptors are diversified much in the same way as B-cell receptors and are structurally similar to antibodies. T cells work in conjunction with the MHC, a gene complex whose proteins combine with small protein fragments inside a cell and take these fragments to the cell surface where they can be accessed by T cells. There are two different classes of MHC: I and II. T cells with CD8 proteins on their surface bind to MHC class I molecules, and those with CD4 proteins bind to MHC class II molecules. Both MHC class I and II molecules bind to protein fragments of the body's own cells if those cells are uninfected or otherwise harmed, though class II MHC molecules are largely responsible for binding to protein fragments from pathogenic microorganisms. CD4 T cells then recognize infection and activate other cells in the immune response. Human immunodeficiency virus (HIV) is particularly toxic to CD4 T cells, resulting in a lower level of these cells, which leads to acquired immunodeficiency syndrome (AIDS).

Emotions and bodies

Emotions are patterns of bodily activity that are often thought to have evolved because they allow an organism to respond to its environment in ways that enable survival and successful reproduction (Rosenberg and Ekman, 1997). In *The Emotional Brain* (1996) Joseph LeDoux says that "Emotions evolved not as conscious feelings, linguistically differentiated or otherwise, but as brain states and bodily responses. The brain states and bodily responses are the fundamental facts of an emotion, and the conscious feelings are the frills that have added icing to the emotional cake" (p. 302). The bodily responses LeDoux refers to include changes in position, posture and movement, facial expression, vocal expression, skin tone, heart rate, blood pressure, breathing rate, and hormone production.

Social affiliation and aversion are correlated with the amount of distance between two bodies, the orientation of one body to another, how much one body leans forward toward another, and the degree of welcome contact between two bodies (Collier, 1985). Two people who disagree but who like each other can show welcome physical contact during arguments (Scheflen and Scheflen, 1972; Collier, 1985). Bodily movement also indicates when someone is startled or suddenly afraid. In these cases, the eye blinks and the bodily movement freezes for a time (e.g., "My spine was frozen in fear."). Observers can infer happiness, sadness, anger, and occasionally pride simply from watching people move (Planalp, 1999).

Perhaps the main route of emotional communication in everyday human interaction is the face. Facial expression includes both the arrangement of the facial anatomy and the direction of eye gaze. There are sixteen muscles used to control facial expression, excluding those involving gaze direction. Surprise is expressed via the occipitofrontalis on the forehead; frowning is accomplished by the corrugator supercilii and the procerus, both of which work on the eyebrows, and by the depressor anguli oris, the depressor labii inferioris, the risorius, and the mentalis; and smiling (or sneering) is mediated by the levator labii superioris alaeque nasi, the levator labii superioris, the zygomaticus major and minor, and the levator anguli oris. Eyelids, the degree to which the eyes are closed, and the openness of the tear duct (i.e., the lacrimal gland) are controlled by the orbicularis oculi. Nasal dilation is controlled by the nasalis, levator labii superioris alaeque nasi, and depressor septi. The lips are controlled by the orbicularis oris. Gaze direction is mediated by the extraocular muscles, which are comprised of four rectus muscles (superior, medial, inferior, lateral) and two oblique muscles (superior, inferior).

Although there have been numerous studies of human facial expression before and since the time of Duchenne's *The Mechanism of Human Facial Expression* (1862) and Charles Darwin's *The Expression of the Emotions in Man and Animals* (1872), it did not receive great attention in modern psychology until behaviorism waned (Rosenberg, 1997). Facial expressions are assessed using either the *maximally discriminative facial movement coding system* (MAX); the *Facial Action Coding System* (FACS), or *electromyography* (EMG) of facial muscles. Both MAX and FACS rely on visual information about faces, while EMG depends only on electrical outputs of facial expression muscles, measured either at or under the skin. While MAX is framed in terms of what are generally considered universally recognizable features of emotional facial expression, FACS attempts to characterize all "visibly discernible facial movement" (Rosenberg, p. 12). However, FACS does not include gaze direction as a parameter.

Using these methods in combination with emotionally evocative stimuli and subject reports, there is evidence that (1) facial expressions and reports of some emotions cohere (Rosenberg and Ekman, 1997; Ruch, 1997); (2) verbal instruction can lead to the involuntary or voluntary suppression and enhancement of facial expressions relating to lower back pain (Craig, Hyde, and Patrick, 1997); (3) lowering the brows, tightening the areas around the eyes, and raising the lips are consistent signs that a person is in pain (Prkachin, 1997); (4) liars control their facial expressions more successfully than other bodily movements while lying; (5) it is possible to detect smiles while lying if one allows for different types of smile (Ekman, Friesen, and O'Sullivan, 1997); and (6) untrained adults have a difficult time distinguishing between what a baby is tasting (e.g., bitter versus sweet) simply by facial expression (Rosenstein and Oster, 1997).

See also HUMAN NATURE, RELIGIOUS AND PHILOSOPHICAL ASPECTS

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HUMAN NATURE, RELIGIOUS AND PHILOSOPHICAL ASPECTS

The suggestion that there is such a thing as human nature implies a specific stance with relation to what a human being is. Do humans have something like a nature? If so, in what does human nature consist? These questions can not be answered from a sole description of specific characteristics, which is one of the main reasons there is a continuous debate over this issue. To say something about what a human being essentially (or in nature) *is,* implies saying something about what humans *ought to be*. Consequently, there is always a kind of normative self-reference in the way the question "What is human nature?" is answered. It is not simply a question of how humans are to understand this or that case, but an articulation of how humans understand, or ought to understand, themselves.

Theories about human nature state something about the place of humans in nature. They also try to define what specifically makes a human being different from other living things. However, as made clear by theologian Wolfhart Pannenberg in *Anthropology in Theological Perspective* (1985), one has to distinguish between the human being as part of nature, and the nature of the human being. These two issues do not necessarily coincide. The former implies a descriptive approach and investigates different empirical and phenomenological aspects that help people better understand their place in nature. The latter is a more normative issue, related to the destiny of humanity in general, as well as to the individual's future and the meaning of the individual life. Its importance is thus also related to interpretation of the place of human beings in history and culture. Taken separately, these approaches offer a basis for the interpretation of human nature from a more naturalistic or humanistic view. Consequently, the sciences usually offer more material relevant to the understanding of the place of humans in nature than for answering questions about human destiny.

A theory about human nature that also takes into consideration an understanding of the human place in nature usually has to account for some or all of the following issues: What specifically makes the human being as a species different from other species? What does it mean to be a person? Do human beings have free will? How does one understand morality, religion, and culture? How are these elements related to language and to human self-consciousness (subjectivity)? Is religion necessarily connected to humanity? Are humans able to act on reasons and principles that cannot be reduced to causes? What is one to think of death? What is the basis for human dignity? Some of these questions can be seen as attempts to differentiate between issues that, in the past, were discussed with reference to the difference between body and soul.

Human nature in non-Western world religions

The variety of ways to understand human nature is expressed also in different world religions. In Hinduism and Buddhism human nature is partly understood from the perspective of the self as part of all that is, and given the task of becoming the non-self. Like other pantheistic religions, both Hinduism and Buddhism affirm that human beings are related to all that is and, simultaneously, how the self is essentially divine. Beyond the empirical human is the human essence, *atman,* which is identical with the ultimate reality, *Brahman*. To overcome individuality and to become part of the encompassing world is the aim of human life. This can be done by transcending the world of the senses. This aim is realized when the self dissolves into the whole after death, but also can be anticipated in different forms of meditational practices.

Whereas Hinduism and Buddhism emphasize how human nature is related to divine nature, the self is generally thought of as distinct from the divine in Semitic religions such as Islam and Judaism. Islam is the religion that most strongly stresses the distinction between God and the world; humanity is seen as dependent upon God and God's will. As in Judaism, God is the creator of humans. The aim of humanity is to realize this dependence and live accordingly—i.e., in gratitude toward God. In Islam, sin is understood as disobedience (*ma'siya*) and not as rooted in human nature. This is different from the most dominant traditions in Christianity. An original aspect of Islam is that all humans are understood as to be born Muslim. It is the cultural environment that changes their essentially Muslim nature in to something else

The Bible offers no developed theory about human nature. Genesis 1: 26–28 describes human beings as created in the image of God (*imago Dei*); this description has given rise to many different interpretations through the history of doctrine. Whoever is made in the image of God is given the task of representing God as the steward of creation, thereby reminding others of God and taking care of God's creation on God's behalf. Hence, human beings are understood in terms of their relation with God; it is this relation that is thought to make humans unique compared to other species. In Psalm 8, humans are placed between the angels and God, indicating their high rank in the order of creation.

Humans are accordingly responsible to God. Simultaneously, they are themselves part of nature; they are made of earth, and without the life-giving breath of God they return to dust. The Bible depicts human life as dependent on the continuous creative activity of God. Humans are not understood in terms of the Greek dichotomy between soul and body, but human life is viewed from different perspectives, such as flesh, body, heart—all notions that can also take on different spiritual meanings. There is a positive affirmation of human embodiment in the Hebrew Bible, echoed in the New Testament teachings on the resurrection of the body and the human need for bodily health, as well as spiritual salvation. One could suggest that human nature from a Judeo-Christian point of view is to be an embodied image of God. This position is affirmed in Christianity, where Jesus Christ is seen as the true human being, and thus reveals what humans are meant to be.

When entering into dialogue with Greek modes of thought, Christian theologians had to articulate the relationship of humans with God from points of view offered by existing philosophical knowledge. This challenged theology to develop an understanding of what it meant to be created in the image of God. The dominating point of view through the Middle Ages became that human nature is unique in rational faculties, understanding, consciousness, and spirit. This view, as expressed by Augustine of Hippo, draws on Platonism, which emphasized rationality and the eternity of the human soul. It also included the view developed by Aristotle in ancient Greece and by Thomas Aquinas during the Middle Ages that put humans on the same level as the rest of nature, but with rationality as the species-unique skill. The eighth-century theologian Johannes Damascenus expresses the prevalent understanding of human nature in the Middle ages: The human being is the image of God because it has reason and free will and is able to be its own master.

Philosophical patterns for a theory of human nature

Two main philosophical trends have had a major influence on understandings of human nature. From the ancient Greek philosopher Plato onwards, the human being alone is able to understand and grasp rationally the world as it is in itself, beyond every change. This ability derives from the rational faculties, expressed in the ability to think. Thus, human nature is closely linked to the ability to think, and to act with thinking as a guide.

Plato articulated the paradigm for a rationalist understanding of human nature. He assumed a dichotomy between body and soul. The soul is the site of reason, and as such it is understood as eternal and (partly and potentially) independent of the body. The body, on the other hand, is mortal and will die. The central struggle in a person's life is to gain control over the physical by means of the rational. As a consequence, Plato sees the flourishing of human nature in its ability to control life with rational means.

The importance of this paradigm is most clearly seen in the seventeenth century rationalism of the French philosopher and mathematician René Descartes, who maintains a sharp dichotomy of body and soul. Descartes claims that while the external world (*res extensa*) operates by mechanistic principles, this is not the case with humans, who are guided by reason. Animals are without reason and hence to be understood according to mechanistic causation only. This view separates the human being sharply from the rest of nature, and suggests that what is specifically human cannot be investigated by the same principles that were utilized by the emerging modern natural sciences.

Philosophically, theories of human nature before the Enlightenment are either rationalist or empiricist in outlook. The empiricist outlook puts more stress on human experience as a condition that shapes actual fulfillment in human life. Hence, one's participation in nature is given a larger role when it comes to determining who a person is. This approach also put more emphasis on the continuity of humans with the rest of nature, and, combined with the experimental approach to investigation of nature, it contributed greatly to the development of modern science. As a result, human nature is here regarded as part of nature, and not something unique. This view is consonant with a religious position that sees the human soul as a function of a complex physical organism rather than as an independent substance.

Challenges from evolutionary thinking

A process similar to the one that began when Christian theology met Greek philosophy developed with the rise of biological insights during the nineteenth century. Theology had to articulate views on human nature that were able to respond to, oppose, and integrate the insights offered by the research of Charles Darwin and others. Obsolete theological theories about the constancy of human nature were now challenged; humans could no longer be seen as a species directly created by God outside of the evolutionary process. Some theological traditions, however, were reluctant to enter into a positive reception of what biology could mean for understanding humanity as part of natural history. Some continue to believe that the biblical stories tell the actual prehistory of humans. This view cannot, however, be held without ignoring the massive amounts of data resulting from scientific inquiry into the prehistory of humans and nature.

Following the rapid development during the nineteenth century of more biologically informed views on human nature, the first half of the twentieth century gave rise to other ways of thinking about human nature. In Germany a special discipline developed called *philosophical anthropology.*

Still tying to appropriate the insights of biology, representatives of this movement attempted to show how humans must be seen as a species that participates in a spiritual realm and is able to relate to the world in a way not available to other living creatures. Some theologians, notably Pannenberg, tried to direct this trend toward integration or mediation between scientific and humanistic insights. Here, physiological traits of humanity are seen as conditions for a religious attitude.

The ability of human beings to transcend themselves is interpreted as the basic trait that can relate us to and realize our divine destiny. On the other hand, the estrangement from this destiny (i.e., sin), is understood by Pannenberg to be conditioned by our constitutional self-centeredness. The content of human life, human identity, and human will are developed in tension between selfishness and divinity.

Integrating scientific knowledge with theological anthropology

Attempts to explain moral behavior (and also religion) in the light of biological evolution have stirred much discussion in which human action is judged by moral standards that reflect the extent to which actions contribute to evolutionary advancement or progress. Critics claim that proponents of this position "fail to demonstrate why the promotion of biological evolution by itself should be the standard to measure what is morally good" (Ayala, p. 47).

The interaction between science and theology has generally consisted of two tasks: determining the range of the validity of the claims offered by biology and sociobiology; and integrating these insights into a more coherent pattern of interpretation of humanity that also takes into account other realms that shape human life and development, such as culture, sociality, history, and subjectivity. The second task has led to more modest positions on what theology can say about the place of humans in nature, and there has been no unconstrained reception of the evolutionary approach to morality or religion in theological anthropology. Generally, theological anthropology that is in dialogue with the sciences tends to navigate between biological reductionism and cultural constructivism. Here, the sciences are seen as elucidating the conditions for a religious or moral position, rather than actually explaining them solely on the basis of biology.

The debate over morality in relation to human nature also exhibits a basic challenge concerning the relation between science and theology: Should theology offer interpretations of insights from science, or should theology try to balance, correct, or contradict these in relation to its own definition of humanity? An example of this problem can be found in the discussion of altruism. Some scientists consider acts of altruism to be contrary to the mechanisms promoting human evolution, while others sees altruism as a positive device for evolution. Theological anthropology seems bound to contradict the first view, while it can relate affirmatively to the second, claiming that evolution operates on other, not naturally given, principles in humanity. Here, culture is seen as a process that is reducible to natural selection. Religion takes part in this. "It makes human beings open to a greater reality before which each individual has infinite value and is absolutely equal" (Theissen, p. 49). Again, a basic pattern seems to underlie any discussion of human nature: Is it to be determined from the point of view of nature and the sciences only, and in accordance with the principles given there, or is it necessary to also establish other independent sources as a means for determining human nature?

Recently, the discussion about human nature has taken a new turn as new developments in biology, especially genetics, contribute to what can be called an *essentialist* view of human nature. This implies that what a human being is, or is to become, is determined by his or her genetic dispositions. Thus, there is an identification of human nature with the given genetic conditions. This view puts little emphasis on the social impact on the formation of humans.

An alternative view, *social constructivism,* emphasizes how humans become what they are as a result of specific cultural conditions communicated within a specific social, social-psychological, and cultural context. Here the actual outcome of biological and other functions is seen as shaped by socially determined conditions. This view is often presented as anti-essentialist, and contains a tacit program for emancipation as gender-based or other socially ascribed roles and demarcations are seen as the result of contingent social developments rather than biological conditions. In psychology, this leads to emphasis on how human relations and culture shape a person's "inner world."

Hence, the way human beings relate to and interpret the world is constituted by them as being relational and social. People are more than "containers" of drives and desires that express themselves in the social and cultural world.

From a phenomenological point of view, humans appear as participants in a multitude of realms related to aspects of both nature and culture. Nature and history is deeply interwoven with human life. This multidimensionality also influences the ways humans understand themselves and relate to the world. However, this phenomenon also suggests that to reduce the interpretation of what human nature is to one or a few aspects implies restricting the possibilities for human self-understanding, and thus, in the long run, for human self-fulfillment.

Consequently, one of the issues that theological anthropology must address when integrating elements from scientific understandings of human nature is the possibility for understanding human beings as more than a product of natural evolution. This is partly due to tendencies towards naturalist reductionism, but also in order to safeguard the human ability to transcend the naturally given conditions of life. This self-transcendence is an important element in human personhood, and is closely linked to the affirmation of human freedom.

Conclusion

There is presently no general agreement as to how to relate to and appropriate insights from the natural sciences in the development of philosophical or religious theories of human nature. Such an agreement should not be expected as long as there is no unified opinion about what a human being is. However, it is possible to distinguish three different models for developing the relationship between religious and philosophical theories of human nature and the sciences:

(1) The natural sciences can be seen as the basis for interpreting religious or philosophical doctrines about human nature, with philosophy and theology working in continuation of what the sciences offer.

(2) A more dialectic or mediating approach tries to incorporate different perspectives on the human being within a coherent theoretical (philosophical or theological) framework. Here, informed by natural sciences, one can formulate theological or philosophical insights without giving them alone the task of determining the overall hermeneutic framework for the development of the theory or doctrine.

(3) A non-dialogical approach denies the relevance of natural science for the understanding and development of philosophical and religious theories of human nature. From the point of view of the sciences, this position can be reversed by one who denies the relevance of philosophy or theology for the understanding of humanity, a position that usually implies a very strong empiricism combined with traits of reductionism.

See also EVOLUTION, HUMAN; HUMAN NATURE, PHYSICAL ASPECTS; IMAGO DEI; PSYCHOLOGY; SOCIOBIOLOGY

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JAN-OLAV HENRIKSEN

HUME, DAVID

David Hume (1711–1776) was born in Edinburgh, Scotland, on April 26, 1711. He was educated at home in the Presbyterian parish of Chirnside, near Berwick, and studied at the University of Edinburgh from 1723 until 1726, without taking a degree. Before leaving the university, he had projected his *Treatise of Human Nature,* and between the ages of fifteen and twenty-three he read widely and methodically in philosophy and other branches of learning, making the study of human nature his principal concern and the source from which he would draw all true conclusions in philosophy, morality, and criticism. In 1734 Hume went to France where he lived quietly for three years composing his revolutionary systematic study of human nature, which was published in three volumes in London from 1739 to 1740. The first volume concerns the understanding, the second the passions, and the third morality.

Finding that the work "fell dead-born from the press without reaching such distinction, as even to excite a murmur among the zealots," Hume penned a review of his own work, which he had anonymously published as a pamphlet: *An Abstract of a Book lately Published, Entitled, A Treatise of Human Nature, &c. Wherein The Chief Argument of that Book is farther Illustrated and Explained* (1740). This remarkable pamphlet is still the best brief guide to the central arguments and conclusions of Hume's theoretical philosophy, so it is unfortunate that a copy of it did not come to light until 1933. Though Hume's *Treatise* was a commercial failure during his lifetime, it is now almost universally regarded as one of the greatest works of systematic philosophy in the English language. However, because he was so disappointed with its reception and was inclined to blame himself for this fact, he recast the first volume into *An Enquiry Concerning Human Understanding* (1748), and the third volume into *An Enquiry Concerning the Principles of Morals* (1758), both of which have become philosophical classics.

The *Treatise* is firmly within the empiricist tradition of John Locke (1632–1704). No ideas are innate: all are derived, either directly or indirectly, from outer or inner experience. Experience is also the arbiter of all belief. Hume may be regarded as advancing a sophisticated Lockean viewpoint that has benefited greatly from the acute criticisms of Locke made by George Berkeley (1685–1753) and others. The universally accepted maxim that "every event has a cause" has no basis in reason. Nor does the ubiquitous assumption that what has happened in the past will happen in the future have any basis in reason. The problem of induction is emphasized and shown to be insoluble by reason alone. The faculty of reason is demoted from its historical hegemony at the same time as the nonrational faculty of imagination is promoted. The imagination, however, does not associate or connect ideas at random. It operates according to principles and associates resembling ideas, or ideas of objects that are contiguous in space and time or that are causally related: "Here is a kind of attraction, which in the mental world will be found to have as extraordinary effects as in the natural, and show itself in as many and as various forms." Reason gives way to instinct, custom, and habit. The three types of association "are the only ties of our thoughts," so "they are really *to us* the cement of the universe." Many items that reason allegedly discerns are reduced to projections or expressions of human nature. In the *Abstract,* Hume unequivocally describes his system as "very sceptical": "Philosophy wou'd render us entirely *Pyrrhonian,* were not nature too strong for it." His considered position is that of a moderate or mitigated scepticism, or one whose otherwise extreme conclusions have been somewhat "corrected" by common sense. This is the Hume who woke Immanuel Kant (1724–1804) from his "dogmatic slumber."

Philosophy of religion

From an early age Hume was preoccupied with religion and science. Before he was twenty, he set down in a notebook "the gradual progress" of his thoughts on theism: "It begun with an anxious search after arguments to confirm the common opinion: Doubts stole in, dissipated, return'd, were again dissipated, return'd again; and it was a perpetual struggle of a restless imagination against inclination, perhaps against reason." It therefore is unsurprising that the *Treatise* as originally written contained several antireligious sections and remarks that Hume prudently removed before publication. In 1737 he told a friend that he was "castrating" his manuscript, or "cutting off its nobler parts" so that it would "give as little offence as possible." He deleted an essay on miracles and probably also one on the immortality of the soul. But notwithstanding these precautions, the very first notice of the work warned readers of its "evil intentions," evident from the book's motto alone: "Seldom are men blessed with times in which they may think what they like, and say what they think".

Hume must have realized that a discerning reader of the *Treatise* would have detected echoes of principles and doctrines prominent in the works of Pierre Bayle (1647–1706), Anthony Collins (1676–1729), Thomas Hobbes (1588–1679), Baruch Spinoza (1632–1677), and other "free thinkers." He therefore should not have been surprised when, in 1745, he applied for a chair in philosophy at the University of Edinburgh, and the local clergy defeated his candidacy by charging him with advocating "universal scepticism" and "downright atheism." They also accused him of "denying the immortality of the soul" and of "sapping the foundations of morality, by denying the natural and essential difference between right and wrong, good and evil, justice and injustice; making the difference only artificial, and to arise from human conventions and compacts." Hume defended himself against these misunderstandings and misrepresentations, but thereafter his writings became increasingly antireligious.

In 1748 Hume published his essay on miracles, in which he argued that there is no reason to believe that any miracle has ever occurred. His argument was attacked by many contemporaries, including William Adams, John Douglas, Richard Price, and George Campbell, whose criticisms are still worth reading. In the same collection Hume devoted an essay to arguing that there is no reason to believe in a particular providence or a future state. This attack on the argument from design was elaborated in Hume's posthumously published *Dialogues Concerning Natural Religion* (1779), which is modelled upon Cicero's *De Natura Deorum*.

The historian Edward Gibbon (1737–1794) regarded the *Dialogues* as "the most profound, the most ingenious, and the best written of Hume's philosophic works." It remains the classic discussion of the argument from design (or argument *a posteriori*), and some regard it as the most important work in the philosophy of religion in English. Had William Paley (1743–1805) carefully studied it, he might never have written *Evidences of Christianity* (1794) or *Natural Theology* (1802). Along the way Samuel Clarke's (1675–1729) *a priori* argument for the existence of God is refuted, and the objections to theism from the existence of evil are forcefully presented.

The *Dialogues* involves three disputants: the orthodox rationalist theologian Demea, the "careless sceptic" Philo, and the scientific theologian Cleanthes, who frequently echoes Bishop Butler's *Analogy of Religion* (1736). Though the argument from design is subjected to sustained criticism, and the attentive reader may be convinced that the canons of scientific reasoning do not issue in theism, at the end Cleanthes seems to emerge as the winner, leading some mistakenly to conclude that Cleanthes speaks for Hume himself. But the *Dialogues* were so "artfully written" that Philo the sceptic only appears to be "silenced." In a private letter Hume said that he objected "to everything we commonly call religion, except the Practice of Morality, and the Assent of the Understanding to the Proposition that God exists." But in the *Dialogues* the concept of God is virtually evacuated of all meaning, so such "assent" amounts to little or nothing. Hume's friend Dr. Hugh Blair, who advised against publishing the *Dialogues* during Hume's lifetime, remarked that they are "exceedingly elegant" and "bring together some of his most exceptional reasonings, but the principles themselves were in all his former works." Most scholars now hold that Philo represents Hume himself. Hume denied that he was an atheist or a deist, so he is perhaps best viewed as a not-so-careless sceptic.

In the *Treatise* Hume argued that morality is not founded on reason, but on passion. Reason alone cannot motivate people to act, and one cannot logically derive statements about what one "ought" to do from statements about what "is" the case. One's sense of justice rests upon self-interest, limited generosity, utility, human conventions, and sympathy or fellow-feeling with the sentiments of others. Jeremy Bentham (1748–1832) said that the scales fell from his eyes when he read this part of Hume's work. Though utility enters into his explanation of the evolution of morality, Hume himself was not a utilitarian. But he was one of the first to insist upon the autonomy of morality, and especially its independence from religious belief. In the *Natural History of Religion* (1757) he inquired into the causes of religion and speculated as to how monotheism had evolved from primitive polytheism, while emphasizing the absurd doctrines and immoral consequences of most world religions. His critics argued that, though his temperament enabled him to be just without being religious, most people require the sanctions of religion in order to be just.

Anonymous writings

Hume counted several of the more liberal Church of Scotland ministers as friends but resented those evangelical ministers who had lobbied against his appointment to a professorship at Edinburgh and Glasgow and who, in the mid-1750s, had unsuccessfully tried to have the Church of Scotland excommunicate him. He carefully cultivated the character of a "virtuous infidel" by encouraging the literary projects of his clerical friends (and potential literary rivals) such as Hugh Blair, Adam Ferguson, and Robert Wallace; and by anonymously publishing favourable reviews of William Robertson's *History of Scotland,* William Wilkie's epic poem the *Epigoniad,* and Robert Henry's *History of Great Britain,* as well as of Adam Smith's *Theory of Moral Sentiments.* The extent of Hume's clandestine literary activity has yet to be determined.

In "My Own Life" (1777), Hume asserted that he was "a man of mild dispositions, of command of temper, of an open, social, and cheerful humour, capable of attachment, but little susceptible of enmity." Adam Smith (1723–1790) testified that his "constant pleasantry was the genuine effusion of good nature and good humour … without even the slightest tincture of malignity, so frequently the disagreeable source of what is called wit in other men." Nevertheless, under cover of anonymity, Hume composed several satires against the clergy and corrupt politicians. "The Bellman's Petition" (1751) is directed against an increase in the stipends of ministers of the Church of Scotland. The far more ambitious, lengthy, and scathing *Sister Peg* (1760) is directed against politicians who had defeated his friends' struggle to reestablish a militia in Scotland. An anonymous satire from 1758 is directed against the commonly felt "antipathy to the corn merchant" during times of famine and "affection for the Parson" who at such times inveighed against the supposedly greedy corn merchants. In it Hume argued that these popular sentiments were based upon ignorance, superstition, and bad reasoning; good reasoning should direct one's passions in the opposite direction, so that one should instead feel affection for the useful corn merchants and antipathy for the useless parsons who "cram us with Nonsense, instead of feeding us with Truth." In these works Hume appears to have revenged himself against those who had previously opposed him.

Political history

In the eighteenth and nineteenth centuries Hume was best known as an historian. His multivolume *History of England* is not only a narrative history but is a philosophical study of the English constitution in which he never misses an opportunity to satirize the folly and hypocrisy of self-interested politicians and clergymen. His historical research was informed by his political and economic theories, which were less conservative than many have assumed. Believing that the first duty of a historian is to be accurate and impartial, while the next is the be instructive and entertaining, he succeeded so well in fulfilling these obligations that his history is still read, while those of most of his contemporaries have sunk into oblivion. Though born a Scotsman, Hume always strove to write an elegant and correct English and to surpass the best English stylists. Occasionally some vanity is evident in his writings, which gives them a conversational tone and an engaging character. Hume believed that good writing "consists of sentiments, which are natural, without being obvious." He repeatedly revised his works in order to perfect them. His views in philosophy, politics, economics, theology, history, and criticism were generally original and unobvious and so artfully expressed as to disguise his artfulness.

Hume died on August 25, 1776, and was buried in Calton Hill cemetery, overlooking Edinburgh. At his internment someone was overheard to say: "Ah, he was an atheist." To which another answered: "No matter, he was an honest man."

See also DESIGN ARGUMENT; EMPIRICISM; GOD; HUMAN NATURE, RELIGIOUS AND PHILOSOPHICAL ASPECTS; IMAGINATION; KANT, IMMANUEL; MIRACLE; MONOTHEISM; MORALITY; NATURAL THEOLOGY

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DAVID RAYNOR

HYPOTHETICAL REALISM

Realism, generally, is the view according to which knowledge refers to objects that actually exist. Hypothetical realism is a weak form of realism based on the theory of the growth of knowledge put forward by evolutionary epistemology. The basic assumption is that human cognitive capacity has evolved through an interaction with the external world. Therefore even if our knowledge has only a hypothetical character and must be open to improvements, the ontological reality of the known (i.e., external reality) is certain.

See also CRITICAL REALISM; EVOLUTIONARY EPISTEMOLOGY; REALISM

TOMAS HANCIL

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IBN RUSHD

See AVERROËS

IBN SINA

See AVICENNA

IDEALISM

Idealism as an ontological or epistemological doctrine holds that reality, or what can count as reality for human beings, is determined by mind. The various ways of specifying the basic role of mind ontologically or epistemologically yield various forms of idealism. As an *ontological* doctrine idealism can hold that reality is basically mental in nature; the physical world is an expression of this mental reality. An argument for the position that what one takes to be material is actually spiritual is that what is actual is process or activity, and mind or spirit is the model of activity. In this sense, *metaphysical idealism* is contrasted with *materialism*. An example is the doctrine of Gottfried Wilhelm Leibniz (1646–1716) that reality consists of active substances, or monads.

As an *epistemological* doctrine, idealism can hold that humans do not have access to a mind-independent reality. However, an epistemological idealism along this line can easily be transformed into an ontological one to the effect that there *is* no mind-independent reality. Idealism in this sense is constrasted with *realism*. The position of George Berkeley (1685–1753) that *esse est percipi* (to be is to be perceived) could be read as an example of an epistemological idealism with radical antirealist claims, which amounts to an ontological *immaterialism*. But Berkeley also argues that sensible things exist independently of human beings in that they exist in the mind of God (*theistic idealism*).

An ontological idealism can hold precisely that there is a reality *beyond* the physical world of sense experience, and this transcendent reality is the basic or true one in that it accords actuality to the relentlessly changing world of sense experience. Humans have access to the ultimate reality beyond the world of sense experience through higher forms of mind, but the true or divine reality transcends the human mind. This form of metaphysical idealism is thus an ontological *realism* (claiming that reality is independent of the human mind). The classic example of a metaphysical idealism as a *transcendent* idealism is the doctrine of the world of ideas in Plato (428–347 B.C.E.).

Epistemological idealism can be reformulated as *transcendental* idealism. The critical philosophy of Immanuel Kant (1724–1804) not only attacks dogmatic metaphysical positions that imply that humans have access to things in themselves beyond the world of sense experience, but also Berkeley's subjective idealism (as Kant takes it to be), which dissolves reality into what humans experience. Instead, according to Kant, space and time, and the categories (e.g., the category of causality) are, as structures of the human mind, also conditions of possibility for the experience of the world. However, this opens the problem that reality is on the one hand "reality-for-us," while on the other hand an ultimate reality beyond this reality is postulated. This problem is dealt with by Johann Gottlieb Fichte (1762–1814), Friedrich Wilhelm Joseph von Schelling (1775–1854), and Georg Wilhelm Friedrich Hegel (1770–1831), whose various positions are collectively labelled *German Idealism.*

Absolute idealism in Hegel seeks to overcome the Kantian split between the world of sense experience and ultimate reality (thing-in-itself) without returning to a dogmatic position. Hegel points out that in having an experience, human understanding of the world and human self-understanding can be changed. This possibility of self-transcendence implied in experience cannot be accounted for if ultimate reality is placed beyond the limits of experience. Hegel's absolute idealism solves the basic task of German Idealism left over by Kant, namely, to account for both freedom inherent in rationality (autonomy) and the embodiment of that freedom. While Fichte emphasizes the activity of the human mind as a productive activity, Schelling sets out to overcome this (as he called it) *subjective idealism* in Fichte by combining a transcendental philosophy and a philosophy of nature. In Hegel's absolute idealism, mind (*Geist*) transcends the divide between freedom and nature by coming to itself through nature and history. Accordingly, Hegel's idealism is not to be captured by the opposition between idealism and materialism, or between realism and antirealism.

As the complex position of Hegel indicates, idealism needs to be reformulated in opposition to its traditional forms. Basically, idealism concerns the problem that human access to reality must tell something about that very reality. From the brief outline above one can extract the insight that in relating to reality human beings are doing something. Thinking is an activity. Humans only relate to reality in interpreting it. This does not imply, however, that reality is what people interpret it to be or that reality is a mental construction. If mind were basic in this sense, people would not be able to discuss the reality of the mind. Instead the crucial argument could be the following: A comprehensive theory of reality must be able to account for the reality of mind and self-consciousness that it itself presupposes. Following this line of argument, idealism could be reformulated as a response to reductive forms of *naturalism* in that it points to the presupposition that human beings as subjects relate to the world, and only as self-interpreting animals are they able to form theories about the world in which they live. The task is to account for both the embodiment of mind and this presupposition of mind.

The question of idealism is thus not only the basic question of science concerning the reality of interpretations and models of reality. Idealism also concerns religious questions about the place of human beings in the world. Religion need not be interpreted along the lines of an idealism that posits a second world beyond the world of sense-experience. A reformulation of idealism as outlined above can instead draw upon the understanding to be found in religion that human consciousness reflects the problem of the embodiment of consciousness itself.

See also MATERIALISM; NATURALISM; REALISM

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ARNE GRØN

IMAGINARY TIME

See COSMOLOGY, PHYSICAL ASPECTS

IMAGINATION

Since Plato, thinkers have recognized human mental capacities for producing images and combining them in ways that do not copy experience.

Philosophers have held many theories about the origin of images. One of the most original is expressed by the seventh-century Chinese Buddhist philosopher Hsuan-tsang in his interpretation of the *Yogacara* writings of the Indian thinker Vasubandhu (c. fifth century C.E.). Hsuan-tsang suggested that the mind has a great storehouse consciousness of images or "seeds" that are "perfumed" into consciousness (as smells incite otherwise hidden memories) by other conscious seeds that have an emotional vector. David Hume, the eighteenth century Scottish Enlightenment philosopher, had a theory of imaginative association modeled on mechanical principles.

Synthesis and construction

Immanuel Kant, Hume's younger contemporary, revolutionized thought about imagination in the first edition of his *Critique of Pure Reason* (1781). He claimed that imagination is a foundational capacity for synthesis in the mind whereby stimuli or impingements from the external world are organized into the basic structures of experience such as a spatiotemporal field and the applicability of concepts to sense data, as explained in Robert Cummings Neville's *Reconstruction of Thinking* (1981). Romantic philosophers such as Thomas Carlyle and Ralph Waldo Emerson developed the view that the structures of imagination are more basic than the surface affirmations of conscious thought and reveal assumptions about reality that are presupposed by other forms of thought. Myths reveal truths more basic than science, for instance. The pragmatic philosopher Charles Sanders Peirce (1839–1914) gave an evolutionary interpretation of imagination such that its deep structures are more likely to be true about basic issues, because corrected over a long evolutionary development, than the reasonings of philosophers. Ray L. Hart in the twentieth century argued that imagination is central to the constitution of human beings before God and is the very form of revelation, inspiring a movement of "theologies of imagination," as analyzed by Fritz Buri in his 1985 article "American Philosophy of Religion."

Imagination has been particularly important in science. For Plato the ideal scientific imagination was mathematical, as Robert Brumbaugh has shown in his *Plato's Mathematical Imagination* (1954) and for Aristotle imagination was the wit to hit upon the third term connecting two otherwise unrelated topics. Whereas some people in Western philosophy might have thought that science is merely a reading off of the lessons of nature, Kant, in the *Critique of Pure Reason,* argued that post-Copernican science forces nature to answer questions of our own imaginative devising. Peirce, at the beginning of the twentieth century, argued at length that all hypothesis construction in science begins with an imaginative guess at the answer and then proceeds by imagination to articulate the guess in theoretical terms that might be tested. Although certain positivistic trends in mid-twentieth century philosophy of science minimized imagination in the testing of hypotheses by focusing closely on the performance of controlled experiments, a counter-movement associated with Thomas S. Kuhn (1922–1995) has been extremely influential. Kuhn argued that the controlled testing of hypotheses, or "normal science," takes place within larger assumed paradigms of what is at stake in the tests, their assumptions and their interpretations as defined by the instruments involved. "Revolutionary science" is when the paradigms themselves are criticized and changed, and this involves much imagination in stepping outside of linear inference. Imagination plays a large role in contemporary thinking about scientific creativity.

In the last two centuries scholars have used the notion of imagination to describe the set of assumptions, thought patterns, and ways of seeing or sensing peculiar to an age or culture. For instance, the imagination of the Hellenistic world of antiquity, when rabbinic Judaism and Christianity arose, included the view that the cosmos is a stack of many spatial levels of which the Earth occupies one, with perhaps many heavens above and hells below. Each level has its characteristic agents, bodies, movements, and patterns of causation. Aristotle's theory that motion above the orbit of the moon is circular whereas that below is straight-line illustrates one version of the multilevel theory; when his theory or others became unquestioned assumptions they formed part of the age's imagination. Biblical references to angels are to be understood as to beings from certain higher levels crossing the boundaries into the earthly level. God often was imagined to occupy the highest level as a being within a spatiotemporal system that includes earthly life at a different place. God's nature might be very different from that of things on the earthly level, for instance that of a pure, immaterial, infinite spirit, but it is connected with the earthly plane by the geography of the cosmic levels. In Christianity (Phil. 2) God's "Son," who has the form of God when with God in the divine heaven, descends to Earth, taking on a nature proper to the earthly level (indeed that of a slave in earthly terms). When human beings make the reverse journey to God, they must take on natures appropriate to the divine heavenly level, for instance "celestial bodies" (1 Cor. 15).

The challenge of science

The challenge of modern science to the imaginative structures of the religions formed in the ancient world is that science itself shapes contemporary imagination to make it incompatible with them. Because of modern science, people know, and assume deep in their imaginations, that beneath the Earth's surface is a molten core, not hell, and that traveling upward leads to outer space, not one or more heavens with different causal structures. Indeed the imagination shaped by modern science assumes a uniformity of measure throughout the entire cosmos: An inch is always and everywhere an inch, a chemical reaction on Earth is the same as it would be in any part of the cosmos with the same conditions, and mathematics applies equally everywhere.

So, in the modern imagination there is no "proper heavenly place" for God if God is extremely different from earthly beings. Theologians have responded to this in various ways. Process theologians (e.g. Charles Hartshorne [1897–2000]) say that God is not so different and is part of the cosmos. They explain this by saying that the differences between God and humans can be expressed within a set of metaphysical measures that apply to the finite God and ordinary things alike. Other theologians (e.g. Paul Tillich [1886–1965]) deny that God is a being at all because to be a being requires having a place; God rather is the ground or creator of all beings and places. Yet other thinkers (pantheists) say that God is identical with the cosmos and differs from any particular finite thing by being all of the things together. Many thinkers reflecting on the differences between the ancient and the modern scientific imaginations say that belief in God is simply incompatible with science, and hence are atheists. Some religious people are able to divide their imagination into one structure for religious matters and another for engaging the world in other respects, although this makes the integrating intent of religion difficult.

The study of "science and religion" sometimes attempts to reconcile contemporary scientific imagination with the ancient imagination that forms the symbols and rhetoric of traditional religions. One approach, called *demythologizing* and associated with Rudolf Bultmann (1884–1976), is to treat the ancient imagination as metaphorical, searching for "religious meaning" distinct from "scientific meaning." Another is to treat the modern imagination and scientific conceptions as themselves open to the literal kinds of beings and causation depicted as heavenly in the ancient imagination. So it is argued that science still allows for miracles and divine agency without denying scientific causation, as discussed in Mark Richardson and Wesley Wildman's 1996 book *Religion and Science* (especially case study one). The problem for religious imagination is related to but not the same as the problem of reconciling ancient and modern theories: It is a problem of apparently conflicting imaginative presuppositions that affect how people perceive and act.

Contemporary scientific imagination poses a potentially more explosive problem for modern life. Until the mid-twentieth century the modern European scientific imagination could picture atoms interacting within the void, or fields of forces affecting material objects within them. Even quantum mechanics could picture the world as having particles that travel along a path but skipping some sections relative to observation. More recent physical science has moved into a mathematical imagination that is not picturable in terms of customary space-time models. Quarks are not like tiny spinning suns, as people had earlier imagined electrons, photons, and neutrons. Only highly sophisticated mathematicians are able to comprehend the relations that added together in bulk might give rise to picturable images. Popularized expressions of many fundamental ideas in microphysics and astrophysics we know to be just plain false to the sophisticated science. This is exactly like the situation regarding certain kinds of theology whose conceptions of God are not picturable in any way and that need to be understood in purely conceptual terms, like mathematics though perhaps with a different dialectical logic. Popular religious expressions, like popular expressions of certain scientific ideas, must be said to be "just plain false," or at least highly misleading, relative to some sophisticated theology that cannot be understood except by the sophisticated. The elitism common to the mathematical imagination in science and the dialectical imagination in theology is more problematic in the religious realm. Whereas technologists can deliver the results of science to a popular world that cannot picture its theory, religions no long have technological priesthoods to mediate unpicturable truths easily to people whose credulity requires traditional religious language.

See also KANT, IMMANUEL

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IMAGO DEI

Imago Dei is Latin for "image of God," a theological doctrine common to Jews, Christians, and Muslims that denotes humankind's relation to God on the one hand and all other living creatures on the other. Traditionally, only human beings are in the image of God, and it is by virtue of this image that human beings are moral and spiritual creatures. Because the image of God is ultimately a doctrine of human nature, it has also been inappropriately used historically to justify racism and sexism.

The term *image of God* is originally found in the biblical book of Genesis, where it occurs three times (1: 26–27, 5: 1–3, 9:1–7). The meaning of the term in the original Hebrew context has been much debated, although current scholarship has moved to understanding it as a designation of stewardship or representation of God's sovereignty. This understanding of the image of God seems to be significantly changed in the Christian New Testament, where it is used primarily by the apostle Paul, who speaks of Christ as being in God's image and of human beings becoming in the image of Christ.

In the Christian theological tradition, the image of God has been interpreted in a wide variety of ways. Most ancient and medieval theologians identified the image of God primarily with the human ability to reason, and it was this quality that was seen to distinguish human beings from all other organisms. Irenaeus of Lyon (second century) made a further distinction between the image and likeness of God, as both terms are used in Genesis 1. As a consequence, later theologians argued whether or not human beings are still in the image of God after the Fall, or whether human beings have lost the image and are now merely in God's likeness. On this understanding, the Fall permanently altered human nature for the worse, the image being restored only through the redeeming action of Christ.

In the wake of the Reformation, the image of God came to be reinterpreted along two primary lines. The first, following Martin Luther (1483–1546), interpreted the image of God primarily in terms of human relationality with God, a move followed especially by Karl Barth (1886–1968) and the neo-orthodox movement. The second followed the dominant philosophical interpretations of human nature in the Enlightenment and after. Particularly after Friedrich Schleiermacher (1768–1834), the image of God has often been seen in the human capacity for self-consciousness.

Many modern theologians continue to be influenced by one of these two strands of thought. The chief influence of the sciences has been to emphasize human continuity with nature, either because of humankind's evolutionary heritage or because of humankind's increased knowledge of the animal world. For this and other reasons, theologians such as Langdon Gilkey (1919–) and Gregory Peterson (1966–) have argued that all of nature should be understood as being in the image of God. Nevertheless, interpretation of the image of God continues to be dynamic, and will no doubt be increasingly influenced by both scientific perspectives and inter-religious dialogue.

See also FALL; HUMAN NATURE, RELIGIOUS AND PHILOSOPHICAL ASPECTS; SOUL

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GREGORY R. PETERSON

IMMANENCE

In theological discourse, *immanence* refers to the presence of God in the world. Conventionally, immanence contrasts with the term *transcendence,* which emphasizes God's separateness and superiority to the world. The two terms, however, are not exclusive opposites, and many theologians balance doctrines of God's transcendence with God's immanence. Historically, theologians have tended to emphasize God's transcendence over God's immanence. In the past two centuries, however, this emphasis has shifted, and many theologians now give more weight to God's immanence. Advocates of panentheism such as Arthur Peacocke (1924–) argue that a theology emphasizing God's immanence is most compatible with modern science.

See also GOD; PANENTHEISM; TRANSCENDENCE

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IMMORTALITY

See LIFE AFTER DEATH

IN VITRO FERTILIZATION

See REPRODUCTIVE TECHNOLOGY

INCARNATION

From the Latin noun *caro,* or *carnis,* meaning "flesh," the term *incarnation* was appropriated by Christianity to designate its belief that in the historical existence of the man Jesus, known to Christians as the Christ, the very being of God has entered fully into human history and the created universe. The incarnation of God implies for believers not only that the person of Christ is the dwelling place of God, his human nature held to be substantially united with the *Logos* (the eternal Word) of God, but that by extension the entire material cosmos is the domicile of God.

In the history of religions, representations of incarnate deities have been a powerful way of communicating a common human intuition that the realm of the sacred is not separate or remote from the empirically given world and that the tangible world is embedded in a mysterious dimension of divine depth. In fact the idea of a divine incarnation is itself a specification of the more generically sacramental character of religions as such. Religions have almost always had a sacramental aspect, by which is meant that their devotees grasp the presence of God or the sacred primordially through the mediation of concrete things, events, or persons that function as revelatory symbols of the divine. The natural world in particular, with its sunlight, flowing water, fertility, life, oceans, mountains, and storms has provided a rich array of symbols by which the sense of a sacred mystery has been communicated to religious awareness. The idea of a divine incarnation in a human being may be understood in the context of the richly sacramental character of religions.

Incarnation in Christian doctrine

A *sacrament* is any property of the visible world through which humans have gathered the impression that the sacred or the divine is expressing itself in an especially intense way. In Christianity, for example, the person of Christ is taken to be the primary symbol or sacrament of God. Theological reflection has even led to the Christian conviction that the fullness of the Godhead has disclosed itself incarnately through the compassion and self-sacrifice of Jesus. Early Christian controversies about how to understand the incarnation led to the teachings of the early Ecumenical Councils (especially First Nicea in 325 and Chalcedon in 451) that Jesus is the incarnate Logos or "Word" of God.

It was an arduous and politically tumultuous process that led to the Christian doctrinal formulations surrounding the incarnation. Denials of Christ's divine nature in the early centuries took the form of Arianism and Nestorianism, both eventually condemned as heretical. And at the other extreme, the humanity of Christ was dissolved into his divinity, in a heresy known as *monophysitism* (literally, "having a single nature"). Christianity has never been completely divested of the tendency to deny that Jesus was fully human, and in recent centuries a decidedly monophysitic leaning has shaped much Christian spirituality. A case can be made that this monophysitic bias has brought needless complications into the dialogue between religion and science.

At the heart of Christian quarrels about the incarnation was the question of how the unchanging, eternal, and almighty God could coherently be said to be fully present in a finite man, one vulnerable enough to be killed by crucifixion. The doctrine of God's incarnation coincides at this point with the shocking idea of a divine *kenosis,* according to which the infinite God empties out the divine substance into the finite world in self-sacrificing love. The God-human paradox of Christ is one that subsequent centuries and contemporary theological discussion have not yet reduced to clarity. Moreover, attempts to clarify the so-called "mystery" of the incarnation have usually led either to the nonacceptance of Christ's divinity or to the suppression of a sense of his humanity. In either case the rejection of a divine incarnation entails a denial of the divine kenosis. The notion of a self-emptying God is one that even Christians have not yet come to terms with, even though it is an idea that can possibly contribute much to the reconciliation of religion and science.

Incarnation in the age of evolutionary science

In this age of evolutionary science, theological reflection on the doctrine of the incarnation has led to speculation that in God's taking on the corporeal reality of Christ the whole universe is, by extension, taken into the divine life. The physical body of Christ is, like every other living organism, the outcome of a cosmic and biological evolution. Hence one may conjecture theologically that the story of the entire universe is inseparable from the existence of the incarnate God. The cosmic story itself, therefore, becomes sacramentally the revelation of God. In light of the idea of God's incarnation in matter the notion of "revelation" can no longer be restricted simply to a brief series of salvific events in the narrow province of terrestrial human history as recorded in the Bible. Rather, the universe as a whole is now seen by many to be the sacramental disclosure of the incarnate God. To some Christian thinkers, especially the Jesuit geologist and paleontologist Pierre Teilhard de Chardin (1881–1955), the epic of evolution is endowed with the deeper meaning that it is from start to finish the process in which God becomes increasingly incarnate in matter, clothing the divine being in the stuff of the universe.

However, as Teilhard de Chardin repeatedly emphasized, "true union differentiates." God's incarnate union with the world is one in which the world becomes even more, not less, distinct from God. Incarnation implies that God foregoes any annihilating relationship to the world. The doctrine of the incarnation, at least as understood by the Council of Chalcedon, implies that God wants to relate to a world that is "other" than God. In order to constitute such a relationship to the universe, however, the presence of God to the world cannot be one in which the divine presence dissolves the world. To seek such an annihilating union of the world in God is an expression of monophysitism, the view that the distinctively human nature of Christ loses itself in the divine nature.

A case could be made that the longing on the part of some anti-Darwinian theists to have a world carefully designed by God, rather than one that evolves more self-creatively and spontaneously, is by implication indicative of a hidden longing for a divine presence that abolishes the world's distinctness from its divine ground. Beneath much current religious anxiety about the implications of Darwinian evolution perhaps there is evidence of a persistent monophysitic hankering for a kind of divine union with the world that melts the world into God.

Any concept of God that theology hopes to reconcile with biological and cosmic evolution, however, would not obliterate the cosmos or human existence in freedom, but would allow for a world that could become increasingly independent. Today a number of Christian theologians see in the doctrine of divine incarnation the basis for such an understanding of the relationship of God to the world.

See also CHRISTOLOGY; EMBODIMENT; KENOSIS; REVELATION; TEIHARD DE CHARDIN, PIERRE

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JOHN HAUGHT

INCOMPLETENESS

See GÖDEL'S INCOMPLETENESS THEOREM; MATHEMATICS

INDEPENDENCE

See MODELS; SCIENCE AND RELIGION, MODELS AND RELATIONS; SCIENCE AND RELIGION, METHODOLOGIES

INDETERMINISM

In quantum mechanics there is deterministic evolution only of the wave function describing a situation: The present state of the wave function determines its future state uniquely and completely. However, the wave function is not directly observable. It determines the probability that measurements will have particular outcomes. This probabilistic aspect is not a consequence of an incomplete description, loss of information, or imperfect observing equipment. It is intrinsic to the nature of quantum reality. It is a manifestation of the limits of classical concepts, such as position, momentum, and energy that are used to describe nature.

The standard interpretation of quantum mechanics includes indeterminism in principle. Perfect knowledge of the present state of the world cannot be obtained even with perfect measuring instruments. In Isaac Newton's (1642–1727) picture of the world (which does not contain the quantum aspects of reality but which can be obtained from the quantum theory as a limiting case when the sizes of objects are much larger than their quantum wavelengths) there appears to be determinism in principle but not in practice. Newton's laws allow the complete prediction of the future from the present state of the world if it is known with perfect accuracy, as envisaged by astronomer and mathematician Pierre Laplace (1749–1827). However, it is impossible for the present state of the world to be determined with perfect accuracy and scientists know that many configurations of matter have the property that any small uncertainty in their initial state is amplified exponentially rapidly with the passage of time. Thus there is indeterminacy in practice. This feature of the Newtonian world is called *chaos.* There have been many attempts to arrive at a full understanding of the quantum version of this type of chaotic unpredictability, but a complete understanding is still to be arrived at.

See also CHAOS, QUANTUM; PHYSICS, QUANTUM

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INFINITY

Infinity in a rigorous sense is a mathematical concept, but the notion of boundless entities, such as the number series and time, have since antiquity touched a deep philosophical and religious chord in the human heart.

Ancient and medieval conceptions

To the ancient Greek religious sect known as the Pythagoreans, the notion of limit was valued as conferring intelligibility and definition, while the infinite (*apeiron*) was associated with void and primordial matter, imperfection and instability. Plato (c. 428–327 B.C.E.) captures this negative sensibility in *Philebus* when he reports that "the men of old" viewed all beings "as consisting in their nature of Limit and Unlimitedness" (16c). Drawing on this background as well as reacting to it, Aristotle (384–322 B.C.E.) adopted the solution of banning anything actually infinite from philosophy. The infinite, he declared, is only "potential," denoting limitless series of successive, finite terms. Time is infinite in this potential sense, without a first beginning or end, but space, which exists all at once, is finite. A similar treatment of infinity is found in Euclidean mathematics, namely in Book 5, definition 4, which allows finite magnitudes as small or as large as desired, but precludes anything actually transfinite.

With the first-century Jewish philosopher Philo and the founder of neoplatonism Plotinus (c. 205–270 C.E.), an actual infinite perfection is attributed in a new positive sense to God to mean that divine perfection transcends every finite case and is immense, eternal, incomprehensible, and unsurpassable. The early Christian leader Augustine of Hippo (354–430 C.E.) in turn stresses in *Confessions* Book 7 that God is infinite according to a special immaterial measure of perfection, invisible to the bodily eye. The eighth-century theologian John Damascene speaks of God in *De Fide Orthodoxa* as "a certain sea of infinite substance" (1, 9). Medieval Jewish mystics such as Isaac the Blind and Azriel of Gerona who were active around the thirteenth century enlist the Hebrew *en-sof* (infinite) to describe the infinite extension of God's thought. Later cabbalists will use the actual infinite as a proper name and refer to "the En-Sof, Blessed be He."

In the mid-thirteenth century, Latin scholastics became concerned with rationalizing divine infinity by framing a coherent philosophical language to discuss various types of infinity and to explore the properties of the actual infinite, such as its noninductive and reflexive character. Two trends are discernible. Thomas Aquinas (c. 1225–1274) built on Aristotle to reach God philosophically as infinite (unrestricted) Being, while his Franciscan counterpart, Bonaventure (1221–1274), drawing more centrally on Augustine, started with a finite degree of ontological perfection and allowed this perfection to be raised to infinity. A new appreciation of the distinction between extension and intensity was thus brought to bear on the infinite, with the notion of intensity serving to mask the paradoxes inherent in the notion of an actual infinite extension. Bonaventure promoted an approach that is introspective rather than cosmological, involving the key premises that the human soul longs for an infinite good (God) and cannot find rest short of reaching it.

Another Franciscan, Peter John Olivi (c. 1248–1298), clarified the difference that exists between a concept taken unrestrictedly (e.g. being) and the determinate infinite case falling under the concept and denoting God (being of infinite intensity). John Duns Scotus (c. 1265–1308), also a Franciscan, formulated on this basis a *univocal* theocentric metaphysics based on adopting the intensive infinite as the "most perfect concept of God naturally available to us in this lifetime." Finally, by stressing the purely semiotic character of the concept and explaining that denoting God by means of the actual infinite does not imply comprehending God, William of Ockham (1288–1348) helped to secularize the discussion and to give the actual infinite a legitimate place in philosophy. The scientists who introduced ideal elements at infinity in geometry in the seventeenth century, namely Johannes Kepler, René Descartes, and Blaise Pascal, were fully familiar with scholastic mainstreaming of the actual infinite.

Modern conception of infinity

In the seventeenth century, Descartes made infinity a keystone of his metaphysics and philosophy of science. The idea of an actually infinite being is innate in the human mind, he argues, and cannot derive from anything finite, not even by extrapolation. Rather, the human ability to conceptualize the limit of an infinite process proves that the concept of the actual infinite is in us prior to the finite. Descartes also insisted that God alone is actually infinite, so that physical space must be described as merely indefinite rather than infinite. Another seventeenth-century scientist to make creative apologetic use of the actual infinite, based on its mathematical properties, was Blaise Pascal (1623–1662). In his famous "wager" argument, he invoked the disproportion of an infinite reward to urge human beings to bet their lives on God, no matter how small the odds. Pascal also invoked mathematical incommensurability to argue that charity infinitely exceeds a life devoted to science, just as a life of science infinitely exceeds a life spent on material pleasure.

The taste for images of absolute transcendence has waned among theologians in recent times, prompting renewed interest in the potential infinite. Process theology, in particular, inspired by mathematician and philosopher Alfred North Whitehead (1861–1947), has explored metaphors connected with the inner unfolding of time and the evolving universe to depict human beings as partners of God's open-ended creativity. Meanwhile, the actual infinite has found rigorous mathematical expression in transfinite set theory, fathered by mathematician Georg Cantor (1845–1918). Cantor not only extended classical number theory by introducing transfinite numbers but proved that there is a hierarchy of transfinite magnitudes, such that, for instance, the infinite cardinality of the continuum (denoted by *c*) is larger than the infinite cardinality of the rational numbers (denoted by *aleph-zero*). The religious dimension of transfinite ideation by no means evaporated on account of this new rigor: Cantor actively sought to enlist Catholic theologians in support of his mathematical discoveries, citing as a personal inspiration Augustine's speculation about God's perfect knowledge of numbers. Cantor's fellow mathematician David Hilbert has perhaps best summarized the dual religious and scientific appeal of infinity in the 1925 address designed to herald Cantor's discovery: "the infinite has always stirred the emotions of mankind more deeply than any other questions; the infinite has stimulated and fertilized reason as few other ideas have; but also the infinite, more than any other notion, is in need of clarification."

See also THOMAS AQUINAS; ARISTOTLE; PLATO; PROCESS THOUGHT; SPACE AND TIME

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INFLATIONARY UNIVERSE THEORY

The Inflationary Universe Theory proposes a brief period of extremely rapid accelerating expansion in the very early universe, before the radiation dominated era called the *hot big bang*. This acceleration is believed to be driven by a quantum field (in effect, some exotic kind of matter) with a repulsive gravitational effect. This can be achieved if the pressure of the field is extremely large and negative (unlike ordinary matter, which has positive pressure).

A specific example is a *scalar field* associated with a potential energy. Such a field "rolls down" the energy surface defined by the potential, and if it is slow-rolling can act like an effective cosmological constant, driving an exponential expansion with constant acceleration. During this epoch, any matter or radiation density other than that of the scalar field is negligible; one is left with an almost constant energy density of the field, often called a *false vacuum* because it behaves like the highly energetic vacuum of quantum field theory. Every 10^{-37} seconds the size of an inflating patch doubles with its energy density remaining constant, so the total mass in the region increases by a huge factor. Inflation ends through decay of the repulsive material into a mixture of matter and radiation, this decay taking place by quantum processes similar to radioactive decay of ordinary matter. The resulting hot expanding gas provides the starting point for the hot big bang era in the early universe.

This scenario provides explanations for some puzzles in cosmology: why the universe is so large, why it is so uniform, and why it is so nearly flat (scientists can not detect the large-scale spatial curvature effects associated with general relativity). Most importantly, this scenario provides an explanation for the origin of large-scale structure in the universe: Clusters of galaxies arise from seed perturbations generated by quantum fluctuations in the very early universe, amplified vastly in size by the inflationary expansion of the universe and in amplitude by gravitational instability after the decoupling of matter and radiation. A major triumph of the theory is that the subtle variations in the cosmic background radiation it predicted have been observed from satellites and balloons.

One popular version of the theory (*Chaotic Inflation*) proposes that ever more inflationary bubbles are generated and expand to vast size, so that on the largest scales the universe is an eternally reproducing foam-like structure of interleaved inflating and post-inflation regions. It should be noted, however, that this proposition is not observationally testable. Indeed, despite its successes, inflation is not yet a fully developed physical theory; in particular the field (or fields) causing inflation (the *inflaton*) has neither been identified nor shown actually to exist. Moreover, various theoretical conundrums remain, for example the problem of exactly how inflation ends, how probable it is that inflation will succeed in starting in an extremely inhomogeneous and anisotropic situation, and how successful inflation can be in smoothing out the universe if arbitrary initial conditions are allowed. (A cosmology is anisotrophic if the physical situation appears very different when we observe from different directions in the sky.) Despite these theoretical problems, and the difficulties in testing the physics proposed, inflation is currently the dominant explanatory paradigm for the physics of the early universe. It has generated immense interest because it provides a major link between particle physics and cosmology, allowing cosmological observations to be used for testing theories in particle physics.

See also BIG BANG THEORY; COSMOLOGY, PHYSICAL ASPECTS; PHYSICS, PARTICLE; PHYSICS, QUANTUM

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INFORMATION

The word *information* is used in three principal senses: (1) the mathematical sense from which arises the theory of digital communication or information theory; (2) the linguistic sense in which it is synonymous with the dissemination of meanings understood by members of a culture; and (3) the formative sense in which information denotes the process of giving shape to some medium or substance.

Kinds of information

Counting-information is mathematical information as defined by American mathematician and engineer Claude Shannon (1916–2001) in a paper on communication theory written in 1948. It has nothing directly to do with meaning; rather it relates solely to an arbitrary measure based upon the theory of probability.

Meaning-information is information in the colloquial sense of knowledge. It is completely different from Shannon's concept of information; it is interpretation-, language-, and culture-dependent.

Shaping-information denotes information as a noun describing the action of giving form to something. It is the oldest sense of the word, originating in the Latin verb *informare,* further reflected in current usage in the German *informieren* and the French *informer.* In this sense, one can speak of the "information" of a system when one imposes constraints upon its degrees of freedom, for example by giving content and structure to a spreadsheet.

Construed in these three ways, *information* crosses boundaries between physics, culture, and mind. In its modern, counting-information sense, especially in the realm of information technology, it seems to have taken on a life of its own, as if the process of rendering things digitally had some intrinsic value apart from its use in conveying meaning and enabling people to shape the world. As with any new technology—the telephone, the television, the motor car, the mobile phone—there is a period during which fascination with the technology itself supplants the wisdom that governs its use, but eventually the more important purposes resume their ascendancy, and the technology once again comes to be seen as no more than a tool.

The religious significance of the science of information is best understood in terms of the articulation of meaning and the establishment of a balanced view of the place of information in human life. That process is in full swing as digitization, the Internet, global communication, and the dissolution of historical boundaries reshape how people conceive of themselves and how they decide to live their lives.

If technology is to serve rather than dictate human needs, it is essential that people retain their capacity to think creatively, which is to generate the ideas that give shape to the technology by investing it with significant meanings. Otherwise human needs will increasingly be at the mercy of the agendas of those individuals, corporations, and nation-states that control the technology, and people will be powerless to resist their influence by giving expression to their own objectives. Articulation of worthy religious goals is one contribution that theology can make to the restoration of the balance between creative thought and technological power.

Counting-information

The mathematical concept of counting-information is based upon binary arithmetic, on the ability to distinguish between two states, typically represented as 0 and 1, in an electronic device. One such distinguishable state is called a *binary unit* or *bit.* Combinations of these states allow data to be encoded in strings, such as 01110101010, that can be stored in two-state devices and transmitted down communication channels. Electronic circuits that can distinguish between only two states are relatively easy to devise, although higher-state devices are possible. The process of encoding facts about the world in such binary strings is called *digitization,* although any particular encoding is arbitrary.

A string of n bits can exist in 2^n; different states and so can represent 2^n different symbols. For example, when $n = 3$, the string can be 000, 001, 010, 011, 100, 101, 110, or 111. If a particular encoding treats these strings as binary numbers, they represent 0, 1, 2, . . . , 7; another encoding might treat them as *a, b,* . . . , *h.* In the early years of computing it was thought that 256 different strings would be sufficient to encode most common letters, numbers, and control codes. The number of bits required to store a given amount of data is therefore usually measured in eight-bit units called *bytes* because of the number of different states of a single byte ($2^8 = 256$). Numbers of bits are counted in powers of 2, so a *kilobyte* is $2^{10} = 1024$ bytes; a *megabyte* is 1024 kilobytes (1024K); and a *gigabyte* is 1024 megabytes. Typical hard disks can now store between 20 and 100 gigabytes.

The states of a binary system are typically called *0* and *1, True* and *False,* or *Yes* and *No.* The system itself is oblivious to these interpretations of the two possible states of a bit, and it is helpful to distinguish between system states and interpretations of those states, for example using the terminology of counting-, meaning- and shaping-information.

The physics of information

The physics of information has given rise to some remarkable results. Shannon showed that there are limits to the rate at which information can be transmitted down a channel with a particular capacity if it is to retain its integrity. Leo Szilard and Leon Brillouin demonstrated that there are fundamental limits to the rate at which information can be processed at given temperatures. Jacob Bekenstein showed that the amount of information that an object can contain—the Bekenstein bound—is directly related to its mass. Some, such as Carl Friedrich von Weizsäcker, have attempted to reconstruct all of physics in information-theoretic terms by conceiving of all physical processes as streams of information. Still others have employed information to look for a fundamental link between entropy and thermodynamics.

The ability to transfer information digitally requires data to be encoded in a binary form; the limitations of such transmission are the subject of information theory as first elaborated by Shannon. However, information is not always easily converted to digital form, especially when it arises from continuous analogue processes, when strict conversion into a discrete coded form is not possible. Neither are the processes that arise from and are useful to human beings easily distilled into the pure digital states required by computers. Some of the most difficult problems faced by those who work in information technology concern the accommodation of computer systems to the untidiness of the data and processes that are typical of human life.

The question of the fundamental nature of information is philosophically and physically deep. It is irrelevant whether one counts to base 2 (as in binary systems) or some other base, but the question of what one is measuring cannot be avoided, and touches some of the hardest questions in physics.

The state of a bit cannot be detected without degrading energy and so increasing the net entropy of the universe. This familiar phrase encapsulates the physical truth that one cannot obtain something for nothing. The Scottish physicist James Clerk Maxwell (1831–1878) once proposed a thought experiment in which a demon capable of detecting the movement of molecules of gas could open and close a trapdoor to allow fast molecules through and keep slow atoms out, thus increasing the temperature of one side of the partition and infringing the second law of thermodynamics. It is now generally accepted that the flaw in this argument arises from the need to increase the entropy of the universe in order to ascertain the state of the molecule; in other words, reading a certain number of bits of information has a thermodynamic cost.

Encoding and encryption

Although encryption is important in the social and political realms affected by information technology, the fundamentals are mathematical and fall within the realm of information theory. The details of modern encryption involve difficult mathematics, but the essential process is not hard to understand. In a simple code or cipher one typically expects to move from an everyday symbol such as 1 or *a* to a binary string such as 000, to store and manipulate that string in a computer, and then to decode the result by reversing the encoding process. Unfortunately, anyone familiar with the encoding can decode the results, and there are times when one does not wish one's messages to be read—perhaps because they contain private commercial information, perhaps because they contain the plans of criminals or terrorists, perhaps because they contain state secrets. So people would like a way to transmit messages in code. But, if the recipient is to decode them, it seems that the decoding rules must also be transmitted, and they could themselves be intercepted, thus compromising the integrity of the message. What is more, it is far harder to know whether an electronic communication has been intercepted than a physical communication such as a book or letter. Instead people need a way to transmit code that does not require the recipient to be told what the encoding process involves. Fortunately, a way to do this has been devised. It is now embodied in the RSA procedure and is as strong or as weak as the number of bits employed in the encryption. This procedure works as follows. Two very large prime numbers that are intrinsically difficult to guess or find (the private key) are used with another number to generate a pair of numbers (the public key) that everyone knows. This process is essentially irreversible in that there is no tractable way to regenerate the original two prime numbers from the public key. This key is then used by anyone who wishes to send me an encoded message to encrypt it, and I, when I receive it, by using my private key, can decode it. Anyone intercepting the encrypted message, even if in possession of the public key, cannot decrypt the message, because they cannot get back to the private key necessary to do so. The strength of the system lies in the size of the public key: a 40-bit number is deemed very difficult to crack; a 128-bit number is deemed almost impossible with current hardware; a 256-bit number could not be decrypted within the lifetime of the universe.

See also INFORMATION TECHNOLOGY; INFORMATION THEORY

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INFORMATION TECHNOLOGY

Information technology (IT) is a general term used to cover most aspects of computer-related technology. Intimately connected with information and information theory, IT deals with the representation, storage, manipulation, and transmission of information in digital form. The religious significance of information technology must be considered in the light of a general theological view of the nature and purpose of human life. Wherever any medium comes to permeate and shape almost all aspects of social and individual existence, questions can be asked about the direction in which such changes lead, and whether they are favorable or inimical to the purpose of human life as conceived theologically.

At the center of the debate lies the broader question of the way in which human beings represent, model, and shape the world. As computer scientist Joseph Weizenbaum (1923–) once put it, ". . . the computer is a powerful new metaphor for helping us to understand many aspects of the world, but . . . it enslaves the mind that has no other metaphors and few other resources to call on" (p.277).

IT began as a tool that human beings could use as they saw fit. In less than half a century it came to occupy an indispensable place in the world. No single human being altogether controlled that rise, and no single human being understands all its implications. The question is rapidly becoming whether human beings will control information technology or information technology will control human beings. Is the demand that people render the processes of human life in forms that are susceptible to digitization forcing them to alter the way they live their lives without giving them a chance to decide whether those changed lives are the ones they wish to lead? That question forces people to examine, perhaps as they have never examined before, the things they think valuable about human life.

Digitization adds a new dimension to the philosophical issues associated with representation. Their sensory system limits what humans can experience, and their intellectual systems attempt to compensate with imagination for those limitations. By universalizing concepts and generalizing theories from experience of particulars, humans have achieved an understanding of the universe of extraordinary power, but that power is not without its costs and its drawbacks. Universal concepts overwrite the particularities of specific instances, just as Plato believed they should, but they lose sight of detail when number and quantity, statistics and probability, replace specificity. Once the world is digitized, this process takes another step toward unreality: A computer stores data in a medium that is incapable of retaining all the detail and presents people with clear-cut images, data, and their constructs that bear a more remote connection to the "real world" than their usual appropriation in human intellectual systems.

Conceptual clarity, of course, has its power and its uses. By concentrating first on idealized simplified situations, processes that are unimaginably complex in reality can begin to be grasped. Computer-generated models of the workings of a living cell—its DNA-replication and division, its immune-system response to attack by viruses, and so forth—illuminate and clarify. But the reality is far less clear-cut, like the digital signals that are represented as beautifully symmetric square waves.

The more pervasive IT becomes, the more it will tend to influence, shape, and direct human lives. In itself it is no more a force for good or evil than other tools, but the range of its influence makes it unlike most other technological changes. The way colored glass affects everything seen through it affords an analogy: As people come to conceptualize the world more and more in terms borrowed from IT, does a time arise when IT comes to shape their view of the world rather than transmit and interpret the world for them to view? At a very basic level, IT does not answer questions about what people should do with it. It is open and indifferent to that use. But it is easy to overlook the way it constrains what people can see, what they aspire to see, and how they see it.

Uses and impact

Security and surveillance. Information transmitted down wires or by radio waves is inherently more vulnerable to interception than information retained in a vault, and so security measures have been developed to match the increased threat. Chief among these are advanced methods of data encryption using encoding systems that are virtually impossible to break, even by the most advanced computer systems.

The ability to render data safe by encryption also has the potential to prevent those responsible for surveillance from decoding messages between subversives, terrorist groups, criminals, pedophiles, and others deemed socially undesirable. There have therefore been attempts to restrict access to high-performance encryption systems, to forbid the transmission of heavily encrypted signals over the Internet, and to prohibit the export of encryption software likely to enable data to be made impregnable to snooping.

Weaponry and conflict. Many of the pressures that have produced advances in the understanding and command of guidance and control systems have arisen from military applications. Warfare has been transformed by advanced technology. "Smart" bombs that seek specific targets, "jamming" devices that interfere with the ability of an enemy to communicate on the battlefield, software viruses that disrupt control systems, eavesdropping on email and digital telephone calls, and electronically disseminated misinformation are all part of the stuff of modern warfare and state security. But smart bombs are not as smart as people are led to believe, and the technology has proved less reliable than military and political leaders insinuate.

Work and society. Information technology significantly alters the parameters governing the way human beings cooperate to achieve their goals. The manufacture of physical objects requires people to be physically present at the site of their construction, in however widespread a way the components are manufactured. Before electronic mail and data communication through the Internet, office work similarly required people to be collected together in their workplaces. Where added value arises largely from the manipulation of data strings—through programming, database design and construction, composing and editing text, and so forth—this physical juxtaposition is unnecessary. People can relate across digital channels through video conferencing in ways that significantly reduce the need and opportunity for physical meetings.

It is not yet clear what the consequences of this shift in work patterns will be, and they are not unique in human history. Just as the industrial revolution drew populations to the cities and the invention of the telephone and radio communication had a major impact on the relationship between society and work, so decentralized but cooperative data-working will effect further changes in that relationship. The threat of loneliness will increase alongside the opportunities for freer work patterns and wider circles of friends, and many have found their experiences of "virtual communities" deeply unsatisfying and unfulfilling.

Viruses, hacking, and censorship

The destruction of the modern Eden of computer-generated communication by deliberately made viruses is a story of almost biblical proportions. The fact that computers must be accessible to a public domain to receive email or access Internet websites makes them vulnerable to attack from malicious software that attaches itself to email and downloadable packages. Executable files and attachments, once opened, infect the host machine, and commonly export themselves to other machines by spawning copies of themselves in bogus messages sent to all or some of the entries in the local address book. The cost to commerce, worldwide, of damage caused by viruses is already measured in billions of dollars, and the cost of antivirus software that struggles to keep up with ways to immunize systems against attack by viruses that become more sophisticated every day has added to that cost.

Hacking, as the process of gaining unauthorized access to another computer is known, is also a major problem. Just as authors of software viruses regard every new defensive shield as a new challenge, so all the sophisticated mechanisms that are employed to prevent unauthorized access to a computer represent a similar challenge. Hackers' conventions set up competitions where the winners are those who can most successfully penetrate the defenses devised by other competitors, and there have been many instances where commercial, national defense, and other secure systems have been penetrated. Some hackers are motivated by no more than the intellectual challenge; some are malicious; some are politically motivated; some are disgruntled employees; some are just socially disenfranchised and angry.

The location of the physical machine hosting a website is not easy to discover. As a result, it is difficult to police the Internet in order to impose any kind of censorship. But it is not clear whose responsibility or entitlement it is to act either as censor or police force. National governments and international organizations are frequently thwarted in their attempts to track subversive, criminal, or other groups by the lack of boundaries on the Internet.

The most obvious cases where some believe censorship should be imposed are sites posting, advertising, and selling sexual material. Others include terrorist organizations, industrial saboteurs, and all sorts of political activists. But here as everywhere the boundaries between public security and private freedom are hard to define.

On the other hand, the difficulty of policing the Internet affords a means to support and help oppressed minorities in countries where they are persecuted. It enhances freedom of speech and expression. It joins together those who find themselves in minorities. It affords the means for all kinds of propaganda wars to be waged. It allows books and art and music to be made available to the poor and to those who live where some material is prohibited or circumscribed. All of these opportunities can, of course, be used for good and ill, and whether the good outweighs the ill remains to be seen.

Reality and virtual reality

Sciences and religions strive to increase knowledge and awareness of what they take variously to be "reality." They have argued extensively and bitterly about the boundaries of "reality," even though their conceptions of reality have grown and changed through the centuries.

The term *virtual reality* is generally taken to denote that new realm of experience fabricated with the aid of IT from the connections between people throughout the world and the capabilities of software to generate new kinds of communication and even new fictional environments in which they can interact. There is nothing in principle to prevent people living on opposite sides of the globe from donning some sort of virtual-reality headset and sharing the exploration of an entirely unreal virtual habitat.

Virtual habitats are not, of course, new. Every fictional book ever written has created virtual habitats for the human imagination, and so, more recently, have films. It is the interactive capacity of virtual realities that is new and poses sharp questions about what people take to be the nature and purpose of human existence.

Individuals and societies

A person's sense of self has typically been associated with a certain geographical locality, a workplace, and a group of friends largely drawn from his or her own nation. People and their cultures are intimately intertwined, even if every culture consists of a myriad of subcultures with their own mores and customs. Selves are distributed through these cultures, and people know themselves as reflected and invested in them.

Because information technology offers people the opportunity to associate with anyone in the world with access to the Internet in a way that far surpasses in immediacy and intimacy anything possible through the telephone or "snail-mail"—through email, video conferencing, websites, chat rooms, and so forth—it is now possible to withdraw from the community defined by a locality, a geographically defined subculture, or a nation-state, and to find (or lose) oneself in the greater culture that exists through the interactions of persons on the Internet.

It is often suggested that computer technology has made human beings less sociable or neighborly. Now that people can choose like-minded conversational partners from anywhere in the world, they are supposedly less minded to socialize with their neighbors. It is not obvious that this is true. Computer technology is as ambiguous as was the television, the telephone, or the motorcar.

Computer communities do, however, break national boundaries without the need for expensive travel, and it is certainly arguable that greater international fraternization will reduce rather than increase the long-term threat of war. What is not clear is the extent to which having the world as one's neighbor will make one less able to negotiate tolerantly with those physical neighbors who surround one every day, or whether exposure only to those who agree will make one less tolerant of those who do not.

Although it is not true that the Internet has spawned "virtual" communities as an entirely new phenomenon—they have always existed through newsletters, journals, conferences, and the like—it has certainly made their activities more widespread and the frequency of their interactions much greater.

Whatever interest people have, there is almost certainly an Internet community that shares that interest. Through online discussions, websites, mass-circulation email, and so forth, such groups establish both their mutual interest and, usually, considerable interpersonal rapport that spills over into wider aspects of life. Participants will commonly share their joys and sorrows, support one another, and exercise general pastoral care for the group. This phenomenon has led some to suggest that the World Wide Web may facilitate the generation of a new kind of religious community in which mutual care and even worship arise within a virtual world rather than geographically close localities or through meeting eclectically in physical buildings.

Embodiment and realism challenged

Science and religion agree that human beings are embodied: finite, physical existence in a physical world, the fact that life has a beginning and an end. These things occasion no disagreement, even if the nature of the beginning and the end do. Human evolutionary history has been dictated by this physicality, and the need to reproduce, feed, and survive as individuals and species has been deeply influential in making all creatures what they are. Virtual selves challenge this history by providing an intelligible alternative in which people might one day come to exist not as physically embodied selves but as remote functional intellectual agents that would stand evolution on its head by adapting the world to fit human imaginations rather than adapting human bodies to fit the world.

Most people recoil from this suggestion because they do not want to lose their physical embodiment. The pleasures of physical contact, whatever they may be, seem so central to what it is to be human that people want to stop in its tracks any process that would render them less than fully physical and embodied.

This instinctive reaction raises clear questions about what people really and genuinely and deeply value as human beings. Science, in its popularly conceived objectivity, cannot answer those questions because it is indifferent to them. For science, human beings and all living and nonliving things simply are what they are; there is no justifiable scientific view of what anything "ought to be." As soon as one asks how things "ought to be," one is in philosophical or religious or ethical territory; science strikes rock, and its spade is turned.

Philosophy and psychology enable people to see that there is no such thing as a raw perception neither filtered nor colored nor shaped by certain sorts of conceptual apparatuses. The world and what is designated *reality* are complex mixtures of sensory stimulation and intellectual construction. Software and hardware change the way human beings see the world, first as a matter of programming necessity, and later because the image of the world they have has been distorted by the information-theoretic format. One is also tempted to believe that the sheer quantity of information available on the Internet somehow replaces the filtered, processed knowledge imparted through more traditional means of dissemination.

IT models and reality

A theology of creation identifies the physical embodiment of persons as playing a major part in the achievement of the creator's purpose. Physical embodiment entails certain limitations imposed by sensory parameters and necessitates certain kinds of community and cooperation. The nature of the world comes to be construed in accordance with certain kinds of gregarious cooperative endeavor.

IT has the power to change the relationship between human's perceptual and conceptual systems and the world. Digital clarity, arising from the cleansing of data of its inconvenient messiness, encourages one to reconfigure the world; virtual communities encourage one to reconfigure the parameters of friendship and love; software models first imitate and then control financial, political, and military worlds. The beginning of the twenty-first century is an age when the residual images of a predigital worldview remain strong; one can still see that there is a difference. A theology of creation suggests that this analogical unclarity is deliberate and purposive; a digital worldview may prove more incompatible with that creative story than currently supposed. The digital reconfiguration of epistemology may yet prove to be the most profound shift in human cognition in the history of the world, and the changes impression of reality that it will afford will present any theology of creation with a deep new challenge.

See also EMBODIMENT; INFORMATION; INFORMATION THEORY

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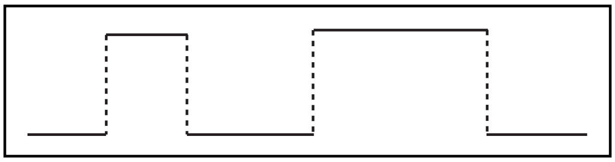
INFORMATION THEORY

The version of information theory formulated by mathematician and engineer Claude Shannon (1916–2001) addresses the processes involved in the transmission of digitized data down a communication channel. Once a set of data has been encoded into binary strings, these strings are converted into electronic pulses, each of equal length, typically with 0 represented by zero volts and 1 by + 5 volts. Thus, a string such as 0100110 would be transmitted as seven pulses:



It is clear from the example that the lengths of pulses must be fixed in order to distinguish between 1 and 11. In practice, the diagram represents an idealized state. Electronic pulses are not perfectly discrete, and neither are the lengths of pulses absolutely precise. The electronic circuits that generate these signals are based upon analogue processes that do not operate perfectly, and each pulse will consist of millions of electrons emitted and controlled by transistors and other components that only operate within certain tolerances. As a result, in addition to the information sent intentionally down a channel, it is necessary to cater for the presence of error in the signal; such error is called *noise*.

This example illustrates the dangers inherent in the differences between the way one represents a process in a conceptual system and the underlying physical processes that deliver it. To conceive of computers as if they operate with perfectly clear 0 and 1 circuits is to overlook the elaborate and extensive error-checking necessary to ensure that data are not transmitted incorrectly, which is expensive both in time and cost.

In 1948, Shannon published what came to be the defining paper of communication theory. In this paper he investigated how noise imposes a fundamental limit on the rate at which data can be transmitted down a channel. Early in his paper he wrote:

> The fundamental problem of communication is that of reproducing at one point either exactly or approximately a message selected at another point. Frequently the messages have *meaning*; that is they refer to or are correlated according to some system with certain physical or conceptual entities. These semantic aspects of communication are irrelevant to the engineering problem. (p.379)

The irrelevance of meaning to communication is precisely the point that encoding and the transmission of information are not intrinsically connected. Shannon realized that if one wishes to transmit the binary sequence 0100110 down a channel, it is irrelevant what it means, not least because different encodings can make it mean almost anything. What matters is that what one intends to transmit—as a binary string—should arrive "exactly or approximately" at the other end as that same binary string. The assumption is that the encoding process that produces the binary string and the decoding process that regenerates the original message are known both to the transmitter and the receiver. Communication theory addresses the problems of ensuring that what is received is what was transmitted, to a good approximation.

See also INFORMATION; INFORMATION TECHNOLOGY

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INTEGRATION

See also SCIENCE AND RELIGION, MODELS AND RELATIONS; SCIENCE AND RELIGION, METHODOLOGIES

INTELLIGENT DESIGN

Intelligent Design is the concept that some things—especially some life forms or parts of life forms—must have been assembled (at least for the first time) by the direct action of a non-natural agent. Proponents of Intelligent Design argue that there is empirical evidence that the universe's system of natural capabilities for forming things is inadequate for assembling certain information-rich biological structures. And if the system of natural capabilities is inadequate, then these biological structures must have been assembled by the action of some non-natural agent, usually taken to be divine.

See also CREATION; CREATIONISM; CREATION SCIENCE; DESIGN; EVOLUTION; SCOPES TRIAL.

HOWARD J. VAN TILL

INTERNET

See INFORMATION TECHNOLOGY

ISLAM

Six centuries after Jesus Christ, the religion of Islam was born in Arabia. By the beginning of the twenty-first century, Muslims, as its followers have always called themselves, number more than 1.2 billion worldwide.

According to Muslim tradition, in 611 C.E. at the age of forty, Muhammad of Mecca received a revelation from God during a spiritual retreat in a cave on Mount Hira outside the city. God's special envoy who brought the message was the archangel Gabriel. At Gabriel's instruction, the illiterate Muhammad recited five short verses that portrayed the spirit of the new religion. In this first revelation, Muhammad—thus by extension all humans—is called upon to know the unknown in the name of God, whose nature is to create things. Humans are then reminded of how, from their lowly animal origin, they became thinking and knowing creatures thanks to God's generous gifts of instruments of knowledge that are best symbolized by the pen. Knowledge is the supreme symbol of

God's infinite bounty and the key to his treasuries. Through sacred knowledge—that is, knowledge through and for the sake of God—humans can attain salvation. In thus emphasizing the saving function of knowledge, Muhammad's maiden revelation as well as many other revelations that were to follow, clearly portrayed the new faith as a way of knowledge. As for Muhammad himself, as told by Gabriel, he had been chosen as the new messenger of God. Fourteen centuries later, Muhammad is widely regarded as one of the world's most influential persons.

Revelations came intermittently to Muhammad over a period of twenty-three years. All of these revelations were systematically compiled into a book known as the Qur'an. According to tradition, the precise arrangement of the Qur'an itself was divinely inspired. This book is central to the religion. It is the most authentic and the most important source of teachings of the religion. The Qur'an is the most influential guide to Muslim life and thought, both individual and collective, spiritual and temporal.

Submission and faith

The word *Islam* means "surrender or submission" to God's will. It also means "peace." In a sense, it is through submission to the divine will that a human attains inner peace. One who submits to the divine will is called *Muslim.* In the Qur'an, the word Muslim refers not only to humans but also to other creatures and the inanimate world. From the Qur'anic point of view, this is not surprising. The divine will manifests itself in the form of laws both in human society and in the world of nature. In Islamic terminology, for example, a bee is a Muslim precisely because it lives and dies obeying the *shavīrah* that God has prescribed for the community of bees, just as a person is a Muslim by virtue of the fact that he or she submits to the revealed "*shavīrah*" ordained for the religious community. In fact, the Qur'an maintains that "every animal species is a community like you," thus implying that God has promulgated a law for each species of being. From its beginning, Islam never made any distinction between what has generally been known in the Western tradition as the "laws of nature" and "the laws of God." In principle, there is harmony between the laws of natural phenomena (*nāmūs al-khilqah*) and the laws of the prophets governing human societies (*nāwamūs al-anbiyā*) since both kinds of laws come from the same source: God the Law-Giver. In asserting such a view, Islam provides an illustrative example of how it seeks to establish points of convergence in the encounter of religion and science.

Islam is noted for the simplicity of its teachings. By professing the testimony of faith "There is no god but God, and Muhammad is the Messenger of God," one enters into the fold of Islam. The whole teachings of the religion are summarized in the six articles of faith (*arkān al-īmān*) and the five pillars of submission (*arkān al-islām*). Muslims must believe in six fundamental truths: God, angels, revealed books, divine messengers, life in the hereafter, and divine plans and decrees. Necessary beliefs go hand in hand with necessary actions, since a human is both a thinking and a believing creature and a creature who acts and does all kinds of things. There are five fundamental obligatory duties for every Muslim, male and female:

(1) To bear witness that "There is no god but God," and to bear witness that "Muhammad is the Messenger of God";

(2) To perform five daily prayers;

(3) To fast from dawn to dusk during the month of Ramadan;

(4) To pay personal and property tax (*zakāt,* literally meaning purification);

(5) To perform pilgrimage (*ḥajj*) in Mecca once in a lifetime, if possible.

The rest of the teachings of the religion are consequences and further elaborations of these pillars of the faith and devotional practices.

Allah and the Qurʾan

God, or *Allāh* in Arabic, is of course the most fundamental reality on which the religion of Islam is based; God created the Muslim soul and shaped the Muslim's thoughts and consciousness. Islam has come to reaffirm the monotheisms of Adam and Abraham. God is absolutely one; the origin and the end of the universe; its creator, sustainer, and ruler. Allah has created the universe for the sake of humans, the best of all creatures. A human being's purpose of existence is in turn to know God. By knowing the universe, humans can know God. This is possible, since God has imprinted numerous signs in the universe. One can also say that

God has imprinted "names" in creation, which are many. Muslim tradition speaks of ninety-nine beautiful names of God, the most mentioned in the Qur'an and the most uttered by the Muslim tongue being *Al-Rahmān* (The Most Compassionate). Muslims adore and celebrate these divine names in numerous ways. Children in kindergartens and Muslim schools called *madrasahs* memorize them by reciting them with melodious voices in a chorus. Artists visualize them with their beautiful Arabic calligraphies. Philosophers exert their intellects to penetrate the deeper meanings of these names through their profound conceptual analysis. Mystics or Sufis contemplate them in their spiritual retreats so that "the heart is empty of everything except God." Such is the profound impact of the divine names as conceived by Islam on the Muslim soul and intellect.

The role of the Qur'an in Muslim life is inseparable from that of Muhammad. He is seen as the perfect embodiment of the Qur'an. A husband and father, a teacher and a businessman, a leader in war and peace, and most of all a spiritual and moral guide, Muhammad is thus the role model for every Muslim of every generation. In Muhammad's own words, his community of believers will not err as long as they are guided by the Qur'an and his way of life.

See also AVERRÖES; AVICENNA; GOD; ISLAM, HISTORY OF SCIENCE AND RELIGION; ISLAM, CONTEMPORARY ISSUES IN SCIENCE AND RELIGION; LIFE AFTER DEATH; SOUL

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ISLAM, CONTEMPORARY ISSUES IN SCIENCE AND RELIGION

In the nineteenth century, the Muslim world's encounter with modern science took the form of a double challenge, simultaneously material and intellectual. The Ottoman Empire's defense against the military rise of Western countries, followed by successful colonization, made it necessary to acquire Western technology, and, therefore, the science behind it. The pressure of modern science on Islam has remained very strong. The West appears as the model of progress that the Muslim world has to reach, or at least follow, through the training of technicians and engineers and through the massive transfer of those technologies that are key to development. But more than anything else, the encounter of Islam with modern science stimulated philosophical and doctrinal thinking, provoked in some fashion by an inaugural event, the now famous lecture titled "Islam and Science," which Ernest Renan (1823–1892) delivered at the Sorbonne in 1883. In the lecture, where he expressed his own positivist perspective, Renan criticized the Muslims' utter inability to produce scientific discoveries, as well as their supposed inability to think rationally. Intellectual Muslims of the time, who were in contact with the Western intelligentsia, considered the lecture offensive. Those intellectuals, with precursor Jamal-al-Din al-Afghani (1838–1897), then championed the idea that Islam never experienced a rupture between science and religion, whereas Christianity, and especially Catholicism, had known a long period of conflict with science. They argued that modern science is nothing other than "Muslim science" developed long ago in the classical era of the Umayyad and Abbasid caliphates, and finally transferred to the West in thirteenth-century Spain, thanks to translations that later would make possible both the Renaissance and the Enlightenment.

For the intellectuals who founded the "modernist" movement within Islam, there is nothing wrong, in principle, with science. What remains unacceptable, however, are the distortions imposed upon science by the materialistic and positivist views held by Western philosophers and antireligious scientists. Modern science could not emerge in the Muslim world, even though it was quite advanced at a certain time, because of "superstitions" that were added to the original religion and encouraged quietist fatalism more than action. The result of this awakening of consciousness as to the progressive slipping into torpor (*jumūd*) of Islamic societies is the modernists' call for a renaissance (*nahḍah*) through reform (*Iṣlāḥ*) of Islamic thinking.

Muslim intellectuals who study relationships between science and religion draw their ideas from Islam's epistemology. Indeed, Islamic tradition emphasizes the search for "knowledge" (*'ilm*), a word that recurs more than four hundred times in the Qur'an and in many prophetic traditions in such forms as "the search for knowledge is a religious obligation," or "search for knowledge all the way to China." This knowledge has three aspects: religious knowledge transmitted through revelation, knowledge of the world acquired through investigation and meditation, and knowledge of a spiritual nature granted by God. Different attitudes about the relationship between science and religion proceed from the different emphases placed on those three aspects. The word (*âyât*) describes both God's signs in the cosmos and the verses in the Qur'anic text. Many passages, called "cosmic verses" (*âyât kawniyyah*) by commentators, direct the reader's attention to nature's phenomena, where the reader is to learn to decipher the creator's work. Islam's fundamental perspective is to affirm divine uniqueness (*tawḥīd*), which ensures oneness of knowledge, insofar as all true knowledge leads back to God. Therefore, there could not be disagreement between data resulting from knowledge of the world and data delivered through revelation, nor could there be the "double truth" (*duplex veritas*) condemned in the Western medieval world and falsely attributed to Muslim philosophers.

The fundamental idea of oneness of knowledge appears in the positions of two major players in the history of Muslim thinking, whose works are still very much read today. Abū Hāmid al-Ghazâl (1058–1111), in *The Deliverer from Error* (*al-Munqidh minī aḍ-Ḍalâl*), champions that rational certitude is granted by divine gift. If there is disagreement between the results of *falsafah* (philosophy and science of Hellenic inspiration) and the teachings of religious tradition, it is because philosophers took their investigations outside the domain of validity of their own fields, which led them to enunciate flawed propositions. In the long test-case opinion (*fatwá*)—the format he used in his book, *On the Harmony of Religion and Philosophy* (*Kitāb Faṣl al-Maqāl*)—Abū al-Walīd Muhammad Ibn Rushd (1126–1198) states that the practice of philosophy and of science is a canonical religious obligation. For him, if there is apparent disagreement between philosophy and revelation, then religious texts must be subjected to interpretation (*ta'wil*) or risk impiety by making God say things that are manifestly false. Contemporary Muslim positions on science fall into three main categories that keep to the idea, in one way or another, of the oneness of knowledge.

The majority position considers, in step with of the reformers of the nineteenth and twentieth centuries, that there is nothing essentially bad about science. The West, the current producer of scientific discoveries, may be blamed only for its materialistic vision and its indifference to morals. What this trend identifies as science are essentially the natural sciences, not human sciences permeated with the West's antireligious values. Science is considered as the means to convey "facts" that are, in essence, totally neutral. What the West lacks is the sense of ethics that some Western scientists exhibit personally, but which is not visible enough or at all in Western societies. Some great Muslim scientists, such as Mohammed Abdus Salam (1926–1996), who won the Nobel Prize in physics in 1979, have advocated the development of modern science in the Muslim word. Such defenders of science evoke the glorious hours of the great period of science in Islam, invoke the long list of Muslim scientists whom "history forgot," and strive to build a future that promotes the emancipating role of education.

This trend has enjoyed considerable growth, while being used, in some fashion, for apologetic purposes. In 1976, Maurice Bucaille, a French surgeon, released *The Bible, the Qur'an, and Science,* a study of the scriptures "in light of modern knowledge," and concluded the Qur'an to be authentic because of "the presence in the text of scientific exposés which, examined in our times, are a challenge to human analysis" (p. 255). The original intent was not to tackle the relationships between science and religion in Islam but rather to take part in the debate between contemporary Orientalists and Islamists on the status of the Qur'an and to bring into the debate elements supporting its authenticity. This idea of the "scientific evidence" of the truth of the Qur'an spread through the Muslim world with the many translations of Bucaille's work, and it became amplified to the point of being a major force in contemporary Muslim apologetics, where the traditional theme of "the inimitability of the Qur'an" (*i'jāz al-qur'ān*) is fully reinterpreted from the perspective of "Qur'anic science." Throughout, "Western scientists" identify in the Qur'an the latest discoveries of modern science (cosmology, embryology, geophysics, meteorology, biology), thereby affirming the truth of Islam. The supporters of this position hold a concept of science that gives no thought to its vision of the world, nor to its epistemological or methodological presuppositions. Some go even further, when—calling on the scripture to deliver quantitative scientific information, such as the very precise measure of the speed of light—they claim to be founding an "Islamic science" on entirely new methods. But, as physicist Pervez Hoodbhoy points out in his *Islam and Science* (1991), which takes a stand against such diversion, "specifying a set of moral and theological principles—no matter how elevated—does not permit one to build a new science from scratch" (p.78). There is only one way to make science, and "Islamic science" of the glorious past was nothing but universal science being practiced by scientists belonging to the Arab-Islamic civilization.

View of the presuppositions of modern science

The second trend rejects this idea of universal science and emphasizes the necessity of examining the epistemological and methodological presuppositions of modern science of Western origin. These presuppositions may not be accepted by the Muslim world. This trend has its roots in critics from philosophy and history of science. Karl Popper (1902–1994), Thomas Kuhn (1922–1996), and Paul Feyerabend (1924–1994) contributed, each in his way, to questioning the notion of scientific truth, the nature of experimental methods, and the independence of science's productions with regard to the cultural and social environment in which they appear. In a climate heavily influenced by the relativism and antirealism of postmodern deconstruction, Muslim critics of Western science reject the idea that there is only one way to pursue science. They strive to define founding principles for an "Islamic science" by planting scientific knowledge and technological activity in the ideas of Islamic tradition and the values of religious law (*sharī'ah*), but with nuances that result from differences of interpretation.

That is how Isma'il Raji Al-Faruqi (1921–1986) elaborated a program of Islamization of knowledge, carried out with the creation in 1981 in Herndon, Virginia, of the *International Institute of Islamic Thought* (IIIT), in response to the experiences and the thinking of Muslims working in North American universities and research institutes. This program is based on the observation of a malaise within the Muslim community (*ummah*), which originates in the importation of a vision of the world totally foreign to the Muslim perspective. For the IIIT, the Islamization of knowledge is all encompassing: It starts with God's word, which can and must apply to all areas of human activity, since God created man as his "representative" or "vice-regent on Earth" (*khalifāt Allāh fī al-ard*). The IIIT's work leads to the conception of a project for the development of a scientific practice at the heart of a religious vision of the world and of society. In fact, the IIIT's undertaking aims more at the social sciences than at the natural sciences, which are considered to be more neutral from the standpoint of methodology.

Other intellectuals, such as Ziauddin Sardar (1951–) and the members of the more or less informal school of thought known as *ijmālī* (self-designated in this fashion in reference to the "synthetic" vision it offers), are also aware of the threat that the West's vision of the world, as it is conveyed by science, represents for Islam. Deeply influenced by Kuhn's analysis of scientific development, they note that Western science and technology are not neutral activities but partake of a cultural project and become a tool for the dissemination of the West's ideological, political, and economic interests. To import modern science and technology into Islam, one needs to rebuild the epistemological foundations of science, keeping in mind the perspective of interconnections between the various domains of human life—a perspective that is peculiar to Islam. Sardar himself has compared the ijmalis' position to al-Ghazālī's.

Assessment of the metaphysical foundations of science

The third trend in Islamic thought is characterized by a deep assessment of the metaphysical foundations that support the vision of the world suggested by Islamic tradition. Seyyed Hossein Nasr (1933–) is its most important proponent. He has been a champion of a return to the notion of "Sacred Science." This trend originates in the criticism of the modern world put forth by French metaphysicist René Guénon (1886–1951), and later by authors in his wake, such as Frithjof Schuon (1907–1994) and Titus Burckhardt (1908–1984), all Muslims of Western origin. Guénon explained how modern Western civilization is an anomaly insofar as it is the only civilization in the world that developed without reference to transcendence. Guénon mentions the universal teaching of humanity's religions and traditions, all of which are nothing but adaptations of the original—essentially metaphysical—tradition. The destiny of human beings is the intellectual knowledge of eternal truths, not the exploration of the quantitative aspects of the cosmos. In this context, Nasr denounces not so much the malaise of the Muslim community, but rather that of Western societies that are obsessed with developing a scientific knowledge anchored in a quantitative approach to reality and in the domination of nature, which results in its pure and simple destruction.

Nasr's position and that of the other defenders of this traditional trend—which some chose to call *perennialist* (in reference to *Sophia perennis,* the "eternal wisdom" of divine origin, which they perpetuate)—inscribes itself not only in the critique of Western epistemology, but in a deep calling into question of the Western idea of a reality reduced to matter alone. The perennialists propose a doctrine of knowledge as a succession of epiphanies, where truth and beauty appear as complementary aspects of the same ultimate reality. They call for a return to a spiritual view of the world and the rehabilitation of a traditional "Islamic science," which would preserve the harmony of the being within creation. In contrast, critics of such a radical position denounce its elitism and emphasize the difficulty of implementing its program in current circumstances.

The various currents within contemporary Muslim thinking are evidence of the intense questioning of the relationship between science and religion. In this context, the Muslim academic world has been operating as a kind of melting pot, where numerous ideas of Islamic or Western origin are elaborated anew in an effort to synthesize them. The fundamental elements remain true to Islamic thinking: the repeated affirmation of God's uniqueness, which unites both creation and humanity; the open nature of the very process of acquisition of knowledge of the world, which, by essence, is unlimited since it originates and ends in the knowledge of God; the narrow interconnection of knowledge and ethics; and, finally, the responsibility of human beings on Earth in their capacity as vice-regents, who must use the world but not abuse it and behave as good gardeners must in their garden. In addition, the metaphysics underlying epistemology and ethics is deeply marked by the dialectic of the visible and of the invisible. Phenomena are the signs of divine action in the cosmos. In fact, God is present in the world, the creation of which God ceaselessly "renews" at every moment (*tajdīd al-khalq*). The articulation of this form of "opportunism" with causality—and modern science's determinism and indeterminism—remains to be elaborated.

Critical thinking on the very elaboration of science as an activity marked by culture is now part of the discourse. In contrast, one must acknowledge that the latest developments in contemporary science—notably those dealing with mathematical undecidability, the uncertainty of quantum physics, the unpredictability of chaos theory, as well as the questioning by biology of evolution, and by neuroscience of conscience—need, no doubt, some further thinking. Indeed, these developments may provide interesting ways to shatter the reductionist and scientist view of the world. They constitute a kind of cornerstone for a metaphysics and epistemology that could give meaning to science as it is done in laboratories and research institutes.

Finally, one has to provide content to the term *Islamic science.* The issue is simultaneously one of ethics (personal and collective), of epistemology, and of the metaphysical *Weltanschauung* it presupposes. When passing from theory to practice, each current of thought must face specific problems resulting not only from its specific position but also from the Muslim world's economic and social difficulties. What remains to be established is the degree to which the most ambitious project—that of Islamic science as Sacred Science—can amount to more than a nostalgic glance at the past and move on to the stage of its actual implementation by a spiritual and intellectual elite. The future of the Islamic civilization's contribution to the development of universal knowledge is tied to the answer that will be given to that question.

See also AVERROËS; AVICENNA; ISLAM; ISLAM, HISTORY OF SCIENCE AND RELIGION

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ISLAM, HISTORY OF SCIENCE AND RELIGION

An account of science and religion in Islam must examine the attitudes of the faith of Islam towards science, as well as the scientific enterprise in Islamic civilization. The first aspect assumes that the perspective of religious thinkers and religious institutions play a determinative role in science through their coercive power or influential authority. The second aspect tempers and even challenges this assumption, for it investigates actual factors that facilitate or hinder scientific practice during particular historical periods and examines how and why particular social and political contexts promote or inhibit science.

These two aspects illustrate the complexity surrounding the term *Islam*. Primarily, *Islam* denotes a faith with particular beliefs, practices, and institutions within its historical and contemporary diversity of expressions. Beyond faith, *Islam* denotes an empire and then a series of successor states during particular periods in world history over a vast expanse of territory in Asia, Africa, and Europe. Despite inherent differences, these regions shared the bond of participating in Islamic civilization, although many inhabitants, including practitioners of science, were not Muslims. The flow of goods, ideas, fashions, and movements of peoples through these regions and the common strands in their intellectual, political, aesthetic, and social outlooks and the social institutions of their elite classes, broadly speaking, characterize these regions with those particular features that are the hallmarks of Islamic civilization. The account of the relationship of science to the faith of Islam at particular locales and times must acknowledge the unifying role played by this civilization. On the other hand, discourse regarding the relationship between religion and science in contemporary Islam is largely dominated by the notion that science, albeit a universal human endeavor, is nevertheless largely developed and exported from external sources, namely the Western world.

Faith to civilization

The faith of Islam was established in seventh century C.E. by the Prophet Muhammad (570-632 C.E.), who, according to Muslim belief, was the recipient of divine revelations, which are collected in the Qur'an, the Muslim sacred text. Facing hostility and opposition, Muhammad fled his birthplace of Mecca, in present-day Saudi Arabia, to Medina. By the end of his life in 632 C.E., he overcame opposition and united almost the entire Arabian peninsula under the banner of Islam. Muhammad had commanded both religious and political authority, and his death raised the issue of the scope and manner of the subsequent exercise of authority. Not surprisingly, there were, and continue to be, a range of responses. Over the centuries, these responses solidified into religious and political institutions, as well as a multiplicity of attitudes regarding their power and authority. Although sectarianism played a role in shaping some attitudes, the lack of a centralized religious institution fostered a diversity of attitudes on all subjects, including the relationship of religion to science.

The nascent community established the primarily political institution of the caliphate following the death of Muhammad. Disagreement between supporters of ʻAlī (d. 661 C.E.) and his opponents over succession and the scope of this office was to later crystallize into the Shīʻī and Sunnī branches of Islam. Over the next three decades, under the leadership of companions of Muhammad, the community commenced a campaign of expansion whereby Palestine, Syria, Egypt, and Iran were soon incorporated into the emerging Islamic empire. These "rightly-guided" caliphs were succeeded by the Umayyads (661–750 C.E.), who continued the expansionist policy. The Umayyads faced several rebellions because of their perceived Arabo-centrism. They also resisted the efforts of religious elites to establish normative frameworks for religious study and institutionalization of religious authority. Since this venture was external to, and at times actively opposed by, the Umayyad court, the genesis of a recurrent conflict between religious and political authorities in Islamic polity was born.

By the early eighth century, the Islamic empire reached its greatest expanse, extending from Spain to the Indus and the borders of China, thereby incorporating Hellenistic and Iranian centers of science, philosophy, and learning. Like its predecessors, this vast empire, with its diversity of peoples, languages, faiths, traditions, and administrative and monetary systems, was susceptible to divisive forces. ʻAbd al-Mālik (r. 692–705 C.E.) therefore sought to unify the empire by instituting Arabic coinage and the Arabic language as the administrative language of the empire. Arabic was soon catapulted beyond the language of revelation and then language of governance to the language of literature, humanities, philosophy, science, and indeed all learned discourse. The attitude towards science at the Umayyad court was utilitarian. Evidence suggests that the court sought physicians who were primarily non-Arab and non-Muslim.

In 750 C.E, the Umayyads were overthrown and replaced by the Abbasids everywhere but in Spain. Even though they had capitalized on the anti-Umayyad sentiment of the religious elite, the

Abbasids soon distanced themselves from their former allies. The litterateur Ibn al-Muqaffa'(d. 757 C.E.) advised the Abbasid Caliph al-Manṣūr (r. 754–775 C.E.) to bring the religious elite under state supervision and to enforce doctrinal and legal uniformity to replace diverse and opposing views. Even though this advice was ignored, the episode illustrates the continuing fluidity of political and religious institutions.

The Abbasids consciously promoted a new order. This was most evident in their establishment of the city of Baghdad in 762 C.E. in present-day Iraq. Baghdad soon became a thriving commercial center and magnet. Above all, it represented the civilization of Islam with its own distinctive literary and aesthetic preferences, attitudes, institutions, and fashion of refinement. The Arabo-centrism of the early Umayyads was replaced by a bustling engagement of peoples of many faiths and persuasions from all parts of the empire. The splendor and richness of the early Abbasid period, under the reign of the Caliph Hārun al-Rashīd (r. 786-809 C.E.), was later immortalized in the *Thousand and One Nights*. But this prosperity came at a price, as the Caliph was forced to grant fiefs to commanders and strongmen. The fiefs soon became semi-independent principalities, leading to the disintegration of the unified empire by the mid-ninth century. Nevertheless, the vision of a unified Islamic civilization endured for several centuries in a number of successor and competing principalities, thriving in even small provincial centers, as well as still-Umayyad Spain.

The "sciences of the Ancients" and religious sciences of Islamic civilization

In his *Introduction to History,* the fourteenth-century historian Ibn Khaldūn (1332-1382 C.E.) notes that urban civilization is characterized by sciences and crafts:". . . as long as sedentary civilization is incomplete . . . people are concerned only with the necessities of life. . . . The crafts and sciences are the result of man's ability to think . . . (they) come after the necessities" (p. 2:347). Ibn Khaldūn includes agriculture, architecture, book production, and medicine among crafts of urban civilization. With regards to the sciences: "one [kind] . . . is natural to man . . . guided by his own ability to think, and a traditional kind that he learns from those who invented it" (p. 2:436). The first kind are the "philosophical sciences"; the second, the "traditional, conventional sciences." Such a distinction was already recognized by Muhammad al-Khwārizmī (d. 997 C.E.) in the tenth century. He divided the sciences into "sciences originating from foreigners such as the Greeks and other nations" and "the sciences of the Islamic religious law and ancillary Arabic sciences." Al-Khwārizmī understood that these attributes denoted origins and were not judgments of intrinsic worth. The religious and Arabic language disciplines were peculiar to Muslims, originating after the advent of Islam; science and philosophy originated in pre-Islamic civilizations and were appropriated into Islamic civilization. Within Islamic civilization, the religious and Arabic language disciplines preceded the appropriation of the "sciences of the Ancients," but the mature development of both was largely coterminous.

The disciplines of philosophical theology (*kalām*) and Islamic law (*fiqh, sharī'a*) are paramount to an account of the relationship between religion and science in Islam. By the late eighth century, Mu'tazilī philosophical theology was immersed in cosmological questions, primarily, creation *ex nihilo* (from nothing), the fundamental constituents of the world, the nature of man, and God's causal role in the world. Notwithstanding a plethora of views in the early period, the late ninth-century consensus held that the world was created *ex nihilo*; its material, temporal, and spatial structure is atomistic; human beings are complex compositions of such atoms (i.e., material beings); and God, who is completely different from created beings, is the primary causal agent, although for the Mu'tazilīs,human beings have a limited causal role (the dissenting Ash'arī view denied human causal agency). These positions are directly opposed to the Aristotelian bent of the "philosophical" sciences.

Reason played a primary role in the epistemology of the Mu'tazilī philosophical theologians. Reason also played a role in early Islamic legal theory. The primacy of reason was attacked by conservative religious scholars, who instead upheld the primacy of revelation and the inspired example of the Prophet Muhammad's personal practice (*sunna*). These sources, in conjunction with the consensus of the religious elite (*ijmā'*) narrowly confined to the two sources of revelation and Muhammad's practice, provided, in their view, the "Islamic" basis for all spheres of human activity.

The conservative movement clashed with the Abbasid Caliph al-Ma'mūn (r. 813–833 C.E.), who, wishing to establish state control over religion, promoted the teachings of the philosophical theologians. Al-Ma'mūn required all judges (who were state appointees) to uphold the doctrine that the Qur'an (technically, God's direct speech) was created. The conservative scholar Aḥmad ibn Hanbal refused to conform and was imprisoned. His continuing refusal resulted in severe beating and home confinement until al-Mutawakkil (r. 847–861 C.E.) revoked this policy.

The early Abbasids were more successful in their policy of encouraging the translation of scientific and philosophical texts into Arabic. This movement began with al-Manṣūr's commission to his physician to translate medical texts into Arabic. By their commitment to a program of appropriating the pre-Islamic scientific and philosophical legacy into Arabic, the early Abbasid view of science went beyond the utilitarian. This perspective is evident in the Abbasid establishment of the institution of a royal library, the House of Wisdom (*bayt al-ḥikma*), which played a role in scientific activity and perhaps translation. These policies resulted in the translation into Arabic by the middle of the tenth century of almost the entire scientific and philosophical corpus of Classical and Late Antiquity and a handful of Sanskrit and Pahlavi texts. This endeavor relied on Nestorian Christian and other translators and financing by patrons beyond the court. The sons of Mūsā are an interesting example. Their father, a former brigand, was befriended by al-Ma'mūn. Mūsā's orphaned sons were raised at the palace and their education was supervised by the caliph. Subsequently prosperous, they patronized additional translations, apart from being excellent mathematicians in their own right. Translation activity was not haphazard. Manuscripts of texts to be translated were eagerly sought. Moreover, entire areas of the classical tradition, for example Greek drama and tragedy, were bypassed deliberately.

Despite the engagement of the Abbasid court, the translation enterprise was not uncontroversial. The scientist and philosopher al-Kindī (d. ca. 870 C.E.), tutor to al-Mu'taṣīm's (r. 833–847 C.E.) son and patron of an early translation of Aristotle's *Metaphysics,* addresses critics in his *On First Philosophy*: "We ought not to be ashamed of appreciating truth and of acquiring it wherever it comes from, even if it comes from races distant and nations different from us." He rejects "those who are in our day acclaimed for speculation, who are strangers to the truth . . . because of their narrow understanding. . . . [They] traffic in religion, though they are devoid of religion" (p. 58–59). The targets of his remarks are undoubtedly philosophical theologians and legal scholars. Despite such controversy, the translation project was a resounding success. It initiated a vigorous scientific and philosophical tradition that extended and flourished beyond Baghdad, persisting in various forms until modern times. During the tenth century, scientists and philosophers were patronized at the courts of the Hamdanids in Syria, the Buyids in Iran and Iraq, the Fatimids in Egypt, and the Ghaznavids in Central Asia, among others.

The movement to appropriate was followed by the naturalization of the "sciences of the Ancients." The extent of naturalization is evident in the education of Ibn Sīnā (980–1037 C.E.), also known as Avicenna. Residing in the eastern city of Bukhara in present-day Uzbekistan, he learned arithmetic from a grocer, then studied with an iterant philosopher, and then, having surpassed his instructor, taught himself the "Ancient" sciences from books that he purchased. An opportunity to examine the private library of the local ruler led to finding rooms of books on all subjects. Ibn Sīnā's account illustrates the widespread engagement with knowledge and the extent of the naturalization of "the sciences of the Ancients," from the practical arithmetic of the grocer, to the iterant philosopher who sought eager students in peripheral locations, to the availability of books in the markets, as well as in private collections. The tenth-century *Epistles of the Sincere Brethren* illustrates another aspect. The epistles represent a sectarian educational program in ethics, politics, mathematics, physics, metaphysics, and the religious sciences, providing an Islamic worldview steeped in a Neoplatonism. Such a perspective was also promoted by the tenth-century Shī'ī Fatimid dynasty in Egypt.

The age of Ibn Sīnā represents the culmination of the naturalization of the "sciences of the Ancients" in Islamic civilization. These sciences were flourishing almost everywhere. Ibn Sīnā was based primarily in Iran. His contemporaries include the astronomer and mathematician al-Bīrūnī (973-1050 C.E.) in Central Asia; the physicist, astronomer, and mathematician Ibn al-Haytham (965-1039 C.E.) and the astronomer Ibn Yunus (d. 1009 C.E.), who were both in Egypt; the physician al-Zahrawī (963-1013 C.E.) in Andalusia; and others. These scientists were at the frontiers of research, yet they were critical of the scientific tradition they had received via the translations and its early proponents. In his encyclopedic work *The Cure,* Ibn Sīnā presents an integral worldview of the "philosophical sciences" encompassing logic, mathematics, physics, and metaphysics. Ibn Sīnā's writings were extremely influential. Many in later generations studied Ibn Sīnā's works, whether as proponents of the "sciences of the Ancients" or as critics.

The fundamental premises of the worldview of the "philosophical sciences" as explicated by Ibn Sīnā are as follows. The world is eternal, produced by cascading emanations of the Divine, who is otherwise removed from, and not directly involved in, creation. The world comprises celestial and terrestrial realms. The celestial realm is constant and unchanging, consisting of emanated spiritual beings—intellects and souls—associated with celestial spheres, which house each of the planets. Planetary motion is voluntary, exhibiting the desire of intellects and souls to imitate the divine. In contrast, the terrestrial realm, consisting of the mineral, plant, and animal kingdoms, is always in flux. Man, possessing intellect, are at the head of the terrestrial chain of being. The celestial realm influences events in the terrestrial realm through emanation. The phenomenon of prophecy, for example, occurs when a particularly receptive human with a powerful imagination is able, through the guidance of a celestial intellect via emanation, to represent pure knowledge in symbolic and cultural garb. Most men are incapable of grasping pure truth and thereby need symbols, rewards, and threats to preserve public order. Revelation is thus replete with symbols, necessitating allegorical interpretation by those with access to pure, theoretical knowledge, namely, the philosophers.

Critique and defense of the "sciences of the Ancients"

Soon after Ibn Sīnā's death, the Shī'ī Buyids were replaced by the Saljuqs, who favored Sunni restoration. By 1055, the Saljuqs controlled Baghdad. They then seized control of the eastern Mediterranean and Mecca and Medina from the Shī'ī Fatimids, and in 1071 they overcame Byzantine resistance in eastern Turkey. Like their Buyid predecessors, the Saljuqs were protectors of the powerless Abbasid caliph. The Saljuq vizier Niẓām al-Mulk (r. 1064–1092 C.E.) established Niẓāmīya *madrasas* (colleges) that, while nominally private, represented official sponsorship of the Shāfi'ī legal school. Already active at the end of the Buyid period, partisans of Ahhmad ibn Hanbal intensified their drive to promote the conservative perspective and caliphal authority. They staged popular uprisings against Mu'tazilī philosophical theology, the mystic al-Hallāj (859-992 C.E.), and even the Hanbalī scholar Ibn Aqīl (1040-1119 C.E.). The movement culminated with the appointment of the Hanbalī Ibn Hubayra (d. 1165 C.E.) to the vizierate by the caliphs al-Muqtafī (r. 1136–1160 C.E.) and al-Mustanjid (r. 1160–1170 C.E.). During the early years of the reign of the later, the property of a judge who had fallen out of favor was seized, and his books on philosophy, including Ibn Sīnā's *The Cure* and the *Epistles of the Sincere Brethren,* were burned.

In a similar environment in 1091, Niẓām al-Mulk appointed the religious thinker al-Ghazālī (1058–1111 C.E.) to teach Shāfi'ī law at the Niẓẓāmīya in Baghdad. Al-Ghazālī spent the first year studying Ibn Sīnā's works and then publishing *The Aims of the Philosophers.* Soon after, he published *The Incoherence of the Philosophers,* with the aim of "[refuting] the ancients, showing the incoherence of their beliefs and the contradiction of their doctrines with regards to metaphysics" (p. 3). The *Incoherence* attacks the cosmology of the "philosophical sciences," in particular, the propositions of the eternity of the world, God's lack of direct involvement in the world evident through God's ignorance of particular events, the determination of particular events in the world by celestial souls, natural causality, and the denial of physical resurrection as described vividly in the Qur'an. Al-Ghazālī's attack, albeit utilizing Ibn Sīnā's philosophical vocabulary, is a defense of the cosmology of the philosophical theologians. The *Incoherence* concludes by charging those who pursued the "philosophical sciences" with unbelief (*kufr*) on the grounds of their denial of creation *ex nihilo,* God's knowledge of particulars, and bodily resurrection.

When al-Ghazālī himself was accused of unbelief, he composed the legal work *The Clear Criterion for Distinguishing between Islam and Unbelief.* He notes that this charge was hurled for sectarian purposes by the Hanbalīs against the Ash'arī philosophical theologians, or the Mu'tazilīs against the Ash'arīs, and so on. Thus, this work is primarily directed against the philosophical theologians and conservative Hanbalīs. Al-Ghazālī asserts interpretive flexibility where the Qur'anic text is susceptible to interpretation, although he proposes strict guidelines. Nevertheless, his attitude of extreme caution in taxing a Muslim with unbelief raises the question of whether he had reevaluated the charge of unbelief against the philosophers in the *Incoherence.*

In his magnum opus, *The Revival of the Religious Sciences,* al-Ghazālī discusses the classification of knowledge from a religious perspective. He divides knowledge into religious and secular, namely, knowledge derived from prophets, and knowledge guided by intellect, observation, or social convention (e.g., arithmetic, medicine, and language). The pursuit of secular sciences beneficial to human activity (e.g., medicine and arithmetic) is praiseworthy even though one need not engage too deeply into them. Geometry and arithmetic are neutral, although some may be led astray by them. Physical sciences, apart from medicine, do not have any utility, and lead people astray. Metaphysics also leads people astray. Thus, most natural sciences and metaphysics are blameworthy. Al-Ghazālī does not evaluate logic, although he describes it as the examination of methods and conditions of proof. He had argued for the Qur'anic basis of logic in many treatises and incorporated logic into his major work on legal theory. Since Aristotelian categorization and analysis were indispensable to logic, al-Ghazālī's action provided a foothold for the "philosophical sciences" at the heart of the religious sciences.

The Andalusian jurist and philosopher Ibn Rushd (1126–1198 C.E.), also known as Averroës, rebutted al-Ghazālī's critique of the "philosophical sciences." Andalusia had undergone a series of social upheavals since the end of Umayyad rule in 1031. After a divisive period of the petty states (1031–1091 C.E.), Andalusia came under the control of the Berber Almoravids (1091–1147 C.E.) and then the Almohads (1147–1269 C.E.), who were invited to defend Spain against the Christian drive to reconquer Spain and oust the Muslims (known as the Christian Reconquista). Under the Umayyad rulers Hishām (r. 788–796 C.E.) and Ḥakam I (r. 796–822 C.E.), Mālikī law became the official Islamic legal school in Andalusia. Andalusian Mālikī law was highly conformist, rejecting any exercise of independent judgment. Mālikī scholars were deeply suspicious of the "philosophical sciences" and theological philosophy, and they even prevented the circulation of al-Ghazālī's works.

When Ibn Rushd was introduced to the Almohad ruler Abū Ya'qūb ibn Yūsuf (r. 1163–1184 C.E.), he hesitated engaging in a discussion regarding the eternity of the world. The ruler then commissioned him to write commentaries on the works of Aristotle, for which Ibn Rushd became known as "the Great Commentator" in medieval Europe. Abū Ya'qūb also appointed Ibn Rushd as judge in Córdoba, Spain. In his *Incoherence of the Incoherence,* Ibn Rushd rebutted each point of al-Ghazālī's critique of the "philosophical sciences." His *Decisive Treatise on the Harmony between Religion and Philosophy* is a legal defense of the "philosophical sciences." Ibn Rushd argues that the Qur'an commands Muslims to recognize their Creator through the study of creation. Since the "philosophical sciences" study creation via demonstration, which is the best manner possible, they permit capable minds to obey the Qur'anic edict. For the masses who cannot grasp demonstrative proof, rhetorical and dialectical knowledge is sufficient. Thus revelation is couched in rhetorical and dialectical language so that the masses can believe, perform religious acts, and maintain public order. Towards the end of his life, Ibn Rushd was briefly imprisoned by the Almohads, who were under external threat from the Reconquista and had to placate Mālikī demands.

Appraisal

It would be a mistake to conclude that the episodes described above illustrate unmitigated religious opposition to science in Islam. The pursuit of science was not explicitly driven by the Qur'anic edict to study creation, despite Ibn Rushd's argument to the contrary. Nevertheless some Muslim scientists, for example al-Bīrūnī, reflect upon the Qur'an in their works. In *The Determination of the Coordinates of Positions for the Correction of Distances between Cities,* al-Bīrūnī quotes the Qur'anic verse, "They consider the creation of the heavens and the earth [and exclaim], Oh our Sustainer, You have not created this in vain" (3:191). He then comments, "This noble verse incorporates all that I have explicated in detail. Only after carrying out its instruction will man arrive at the heart of the sciences and understanding" (p. 3). Al-Bīrūnī illustrates the attitude that prompted the exploration of scientific problems connected to religious practice—the determination of times and direction of prayer, the sighting of the crescent moon, and the determination of the twilight and sunset. As a result, the office of the timekeeper versed in mathematics and astronomy and affiliated with the Friday congregational mosque became an important institution in some regions.

The "philosophical sciences" had always been studied privately and had no place in the curricula of the post-eleventh century, increasingly dominant institution of the *madrasa*. The exceptions of arithmetic and medicine at some *madrasas*. Yet the "philosophical sciences" were deeply rooted in the Islamic world and were incorporated into the religious sciences, as evidenced by Al-Ghazālī's incorporation of logic into Islamic legal theory. In his massive commentary on the Qur'an, Fakhr al-dīn al-Rāzī (1149-1209 C.E.) turns to the "philosophical sciences" to discuss theories of light, planetary motion, and other such matters. This attitude is also evident in the philosophical theologian al-Ijī (d. 1355 C.E.), whose work *The Stations of Philosophical Theology* became the standard textbook in the Sunnī *madrasas* and was the subject of numerous commentaries across the Muslim world. The same can be said of other popular texts. Clearly the interaction of religion and science in premodern Islam was a complex phenomenon and requires due diligence to the specific contexts that supported, or opposed, the scientific enterprise.

See also AVERRÖES; AVICENNA; CREATION; GOD; ISLAM; ISLAM, CONTEMPORARY ISSUES IN SCIENCE AND RELIGION; METAPHYSICS

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JUDAISM

Judaism is a monotheistic, scriptural religion that evolved from the religion of ancient Israel during the Second Temple period (516 B.C.E.–70 C.E.). Two core beliefs shaped the attitude of Judaism toward nature and toward the systematic study of nature (i.e., science): that God is the creator of the universe and that God revealed God's will in the form of Law—the Torah (literally "instruction")—to the chosen people, Israel.

The doctrine of creation facilitates an interest in the natural world that God brought into existence, even though the details of the creative act remain beyond the ken of human knowledge. Several Psalms express the notion that the more one observes nature, the more one comes to revere its creator, since the world manifests order and wise design. Awareness of nature's orderliness leads the observer to praise and thanksgiving and evokes awe and reverence. The study of nature, then, did not conflict with love of and obedience to God. Indeed, in the Middle Ages, Jewish philosophers regarded the study of God's created nature as a religious obligation. Nonetheless, the natural world was not to be worshiped for its own sake; that is the form of idolatry against which Judaism rails. In Judaism, nature always points, rather, to the divine creator who governs and sustains nature and who intervenes in human affairs, making God's will known through the performing of miracles, the greatest of which is the revelation of the Torah to Israel.

Rabbinnic attitudes

Even though in principle there is no theological impediment to study the natural world, the degree to which Jews should engage in scientific inquiry has always been debated in traditional Jewish society. Since philosophy and science originated in ancient Greece, the debate pertained to the cultural boundaries of Judaism, especially because Jews encountered Hellenistic culture as the culture that occasionally oppressed them, curtailing Jewish political independence and threatening Jewish mores. Since immersion in Greek culture could conceivably lead one away from commitment to God's Torah and the life it prescribed, rabbinic literature contains suspicious attitudes toward "alien wisdoms" (*hochmot hitzoniyot*) and issues a call to avoid teaching "Greek wisdom" to children. This caution is found side by side with information about rabbis who promoted the Greek *paideia* or who were themselves learned in the natural sciences. More problematically, the primacy of Torah study itself was justified by the claim that the revealed Torah, identical with God's wisdom, encompasses all true knowledge. If so, Jews have no need to pursue knowledge outside the perimeters of Torah. It is difficult, then, to generalize about the rabbinic attitude toward the study of nature and determine the precise scope of rabbinic knowledge of the science in their day.

The main scientific data in rabbinic literature pertains to astronomy and human physiology. Several rabbis (e.g., R. Yohanan ben Zakkai, Gamaliel II, and Joshua ben Hananya) were expert astronomers, using observed data for the calculation and adjustment of the lunar-solar calendar. The rabbinic corpus is also replete with information about the motions of celestial bodies, the four seasons, the planets, the zodiac, and even comets. The picture of the universe in Talmudic texts has the Earth in the center of creation with heaven as a hemisphere spread over it. The Earth is usually described as a disk encircled by water. Interestingly, cosmological and metaphysical speculations were not to be cultivated in public nor were they to be committed to writing. Rather, they were considered as "secrets of the Torah not to be passed on to all and sundry" (Ketubot 112a). While study of God's creation was not prohibited, speculations about "what is above, what is beneath, what is before, and what is after" (Mishnah Hagigah: 2) were restricted to the intellectual elite.

Within the created world, the human body was of utmost interest to the rabbis, although their information about human anatomy was shaped by religious concern for ritual purity. Rich in details about the skeleton, the digestive organs, the respiratory system, the heart, the genitals and other organs, the rabbinic corpus also includes rather fanciful material and is totally lacking in graphic illustration. The discussion is concerned primarily with physical disfigurements that disqualify men from the priesthood, with rules concerning menstruating women, and with other sources of ritual pollution. The rabbinic corpus also includes informative claims about embryology, diagnosis of diseases, and a host of medications and hygienic strategies for prevention of disease. Indeed, the physician is viewed as an instrument of God, treated with utmost respect, and several Talmudic scholars were themselves physicians. Nonetheless, the rabbinic discourse about scientific matters was unsystematic, primarily because it was embedded in the interpretation of Scriptures. Whether the rabbinic legal reasoning as a whole could be considered "science" is debated in contemporary times, reflecting twentieth-century changes in the philosophy of science.

Scientific learning in the Middle Ages

The cultivation of science as a public, albeit elitist, activity began in earnest in the ninth century, when most of world Jewry lived in the orbit of Islam. Greek and Hellenistic philosophy and science were translated into Arabic and stimulated the rise of Islamic rationalist theology. Writing in Arabic, Jews emulated Islamic scholars, reinterpreting rabbinic Judaism in rationalist categories derived from Muslim neo-Platonism and Aristotelianism. Jewish scholars studied all branches of the sciences and a few Jews (e.g., Isaac Israeli, Moses Maimonides, and Levi ben Gershom, known as Gersonides) achieved distinction in the non-Jewish world. Jews participated in astronomy at the court of Alphonso X and were largely responsible for the construction of the Alphonsine Tables for computing planetary positions that remained popular until the mid-seventeenth century. Lacking an institutional setting, Jewish scientific learning was an autodidactic, bookish activity of translating texts of the liberal arts and natural philosophy from Arabic into Hebrew and occasionally from Hebrew into Latin, writing commentaries on them, and working out the theological implications of the apparent conflict between revealed knowledge ("religion") and knowledge discovered by human reason ("science"). One primarily exception was the astronomical observations of Gersonides (1288–1344), who built an instrument to study the distance between the stars, the Jacob Staff remained in use by European navigators until the mid-eighteenth century.

Moses Maimonides (1135–1204) articulated the most sophisticated synthesis of science and Judaism. In principle, he held, there can be no contradiction between the inner, nonliteral meaning of the Torah and what is true in the sciences of physics and metaphysics. Apparent conflicts emerge either because a nondemonstrable scientific theory is adopted (for example, Aristotle's view that the world is eternal and his explanation of celestial motions), or because the biblical text is not interpreted in light of philosophy and science. For Maimonides, who accepted Aristotelian science in regard to processes of the sublunar world, possessing knowledge about the physical world was a religious obligation, because accurate knowledge about the physical world leads one to understand how God governs the world (i.e., God's attributes of action). However, Maimonides's radical negative theology, according to which scientific knowledge does not yield valid knowledge about God's essence, placed a limit on science and made the intellectual perfection (the goal of human life according to Maimonides) unattainable.

For the subsequent four centuries, Maimonides's followers translated scientific literature into Hebrew and interpreted Scripture as an esoteric text that contains scientific-philosophic truths. To disseminate philosophic-scientific knowledge Jewish scholars composed encyclopedias that summarized known scientific data in the linguistic sciences (logic, rhetoric, and grammar), the mathematical sciences (arithmetic, geometry, optics, astronomy, music, mechanics, algebra), the physical sciences (based on the eight books of Aristotle's *Organon*), metaphysics, and politics (including ethics and economics). This vast knowledge was deemed necessary for the attainment of intellectual perfection, resulting in immortality of the intellect. Whether it was also sufficient knowledge for immortality was vigorously debated, especially after Maimonides's theory of divine attributes was modified by Gersonides to mean that scientific knowledge does yield positive knowledge about God's essence. For Jewish philosophers to attain religious perfection, they had to be philosopher-scientists.

Jewish scientific learning during the Middle Ages was broad in scope and ambitious in aim but it was not unproblematic. First, scientific learning was cultivated only by Jews in Mediterranean communities of Spain, Southern France, Italy, and North-Africa but did not penetrate the Jewish communities north of the Alps. Second, the Jewish scientists-philosophers did not have an institutional setting and did not receive official support for their inquiries. Unlike their Christian neighbors, Jews did not create universities, and the scientific curriculum was not incorporated into the rabbinic academies for higher learning. Third, scientific knowledge was cultivated by a very small number of experts and did not engage the community at large. Finally, there was organized opposition to the cultivation of the sciences, spearheaded not just by rabbis who regarded secular knowledge to be irrelevant or even undermining to the authority of the Jewish tradition, but sometimes by Jews who were themselves quite knowledgeable in the sciences. The Maimonidean controversy that engulfed world Jewry during the thirteenth century and resurfaced in the fifteenth and sixteenth centuries indicated that the cultivation of science remained problematic even in the Middle Ages.

Early modern period

In the early modern period (sixteenth through eighteenth centuries), the Maimonidean tradition lost its interpretative power and was replaced by *Kabbalah,* the Jewish mystical tradition, as the official theology of Judaism. In a way, the turn to Kabbalah was an attempt to overcome the restrictions of Maimonides's radical negative theology. For the kabbalists, knowledge of God's essence and intimacy with God were to be attained not through observation of the material world interpreted by Aristotelian scientific theories, but through fathoming the symbolic meaning of God's revealed Torah. Constructed out of the building blocks of the Hebrew alphabet, nature mirrors God's essence and the primordial Torah is the key to decipher nature's symbolic structures. The kabbalists regarded nature not as observable, measurable mass, but as an information system that has to be decoded. Their elaborate speculations about the origins of the universe were ultimately a hermeneutic activity, framed by the very language of Jewish canonic texts. This approach to nature was in accord with trends in Renaissance culture and usually went hand in hand with preoccupation with magic, astrology, and alchemy, but it did not necessarily prevent the Jewish scholar from also being informed about new scientific discoveries in astronomy, human physiology, botany, zoology, and mineralogy.

While Kabbalah did not preclude one from interest in nature, on the whole, Kabbalah probably retarded the involvement of Jews in the scientific revolution of the seventeenth century. Jewish scholars played a marginal role in the development of early modern science, although a small number of Jews were aware of the emerging new sciences. David Ganz (1541–1613), for example, corresponded with the astronomer Johannes Mueller and was personally familiar with Johann Kepler and Tycho Brahe. The first Jew to mention Copernicus and praise him, Ganz nonetheless adapted Brahe's model, which reconciled the Copernican and Ptolemaic systems on the basis of actual observations. For Brahe, Ganz translated the Alphonsine Tables from the Hebrew into German, and for his Jewish audience Ganz composed in Hebrew the history of Jewish involvement in astronomy. That book, however, was printed only in 1743, indicating a relative lack of interest in the subject among Jews. A typical Jewish response to the heliocentric theory was voiced by Isaac Cardozo (1604-1681), the most scientifically informed Jew of his day, who rejected it on religious grounds and adduced nineteen biblical verses against the theory. By contrast, Joseph Solomon Delmedigo (1591–1655), who had contacts with Galileo Galilei and who was the first Jewish scholar to use the recently invented logarithmic tables, parted company with the followers of Ptolemy to espouse the Copernican system. Delmedigo was also a student of Kabbalah, which he proceeded to criticize, but he promoted knowledge of the empirical sciences as a way to alleviate the miserable conditions of Jewish life in Europe's ghettos. The small cadre of Jews who earned doctoral degrees from European universities, especially in medicine from the University of Padua, did not change the fact that interest in the natural sciences was marginal in Jewish culture during the early modern period. Instead, the study of Halachah and Kabbalah—both are elaborate, textual, self-referential, abstract edifices—preoccupied Jewish intellectual interests. The ethos of Jewish traditional life in eighteenth-century Europe remained largely uninformed by the scientific revolution.

In the late eighteenth century, a small group of Jewish intellectuals in Germany began to agitate for change. Inspired by the Enlightenment, these Jews insisted that Judaism must embrace scientific knowledge or else stagnate. Desiring social integration and an end to Jewish segregation and persecution, the advocates of Jewish Enlightenment (*Haskalah*) were very critical of traditional Jewish education and encouraged Jews to study the sciences in order to become fit to enter modern society. The proponents of Haskalah worked tirelessly to persuade European states to grant Jews equal civil rights.

France was the first country to grant citizenship to Jews (1791), as the logical consequence of the Declaration of the Rights of Man (1789). Yet the struggle for legal emancipation lasted until the 1870s in central Europe and was achieved in Russia only with the revolution of 1917. As citizens, Jews who flocked to the universities of western and central Europe embraced the natural sciences as secular pursuits that promised social progress and modernization. Some even converted to Christianity in order to be able to hold academic positions, and for those who remained nominally Jewish, science replaced traditional Jewish Torah-study and was devoid of religious meaning. In the nineteenth century, individual Jews contributed immensely to a plethora of natural sciences, but they did so as individuals and not as members of Israel, God's chosen priestly nation. The secularization of Western (Christian) culture, which privatized religion, and the prevailing scientific theories of classical physics exacerbated the perception that science and religion were diametrically opposed. The main Jewish responses to modernity—Reform, Conservative, and Orthodoxy—articulated distinctive approaches to the perceived tension.

Strands of modern Judaism

Reform Judaism essentially denies that there is a conflict between Judaism and science. Reform thinkers assume that Judaism is a rational religion that welcomes the scientific, ongoing sequence of observation, hypothesis, experimentation, and conclusion, with each conclusion subject to further investigation by the same method. The rationalist spirit of Reform Judaism intended to strip Judaism from the morass of ossifying, legalistic minutiae and bring to the fore the timeless, universal truths of Judaism. The rationalist temper, which led Reform Judaism to discard many traditional practices or invent new rituals, did not necessarily mean endorsing the most challenging scientific theory of the nineteenth century—Darwinism. In the United States, the radical reformer David Einhorn (1809–1879) sneered at the idea that humans descended from lower animals, and his opponent, Isaac Mayer Wise (1819–1900), also took a dim view of Darwinian thought. However, by the 1880s several Reform rabbis attempted to reconcile religion with the new science and defended Judaism's superiority over other religions because of its nondogmatic, ever-evolving character. Reform rabbis accepted biblical criticism and viewed the Bible itself, and not only rabbinic Judaism, as a product of history. To their chagrin, however, Reform rabbis had to contend with Protestant biblical criticism that used the Darwinian model to prove that Judaism was a primitive religion out of which evolved the superior religion of Christianity.

Interest in the relationship between science and religion is stronger in Conservative Judaism because it takes the rabbinic tradition to be obligatory, while acknowledging that it evolved over time. More than the natural sciences, the academic discipline of history was the scientific inquiry that concerned Conservative Judaism. In the nineteenth century, Conservative scholars accepted the evolutionary model and applied it to the history of Jewish law, leaving the Bible untouched. In the twentieth century, the critical method has been applied to the biblical text and the perceived challenge by science is rebuffed by saying that the revealed biblical text did not intend itself to be understood literally but as a poetic statement of certain truths: that the world was created by God, and that God planned it carefully and designed it to be hospitable to human beings. These conclusions are consistent with contemporary scientific theories in physics and cosmology. Indeed, the twentieth-century move away from classical physics to a new model of the universe explained by relativity theory or by quantum mechanics enabled some Conservative rabbis to make the biblical narrative more intelligible. Rabbi Lawrence Troster, for example, argued that the Anthropic Principle shows that the universe is not a neutral entity, empty of purpose and meaning, and that partnership between science and religion is possible and desirable. For him the Big Bang theory can lead to an intellectual or emotional enthusiasm for the creator. Conversely, contemporary physics should lead to rethinking the meaning of the doctrine of creation, especially creation in the image of God, and of the problem of evil. Troster's studies are consistent with the work of Norbert Samuelson, the only Reform rabbi who has made a significant contribution to the dialogue of science and religion.

The main area for the confluence of science and religion in Conservative Judaism is bioethics. Conservative legal thinkers such as Elliot Dorff maintain that scientific research is both possible and potentially fruitful and that contemporary interpretation of Halachah must be informed of advances in science and technology. Yet, scientific activity cannot be taken for its own sake: Scientific means and ends have to be evaluated by religious values. Science, and especially its application in technology, can be used to solve legal problems or to alleviate legal restrictions. Though rabbis must be informed about science, the scientific facts of every disputed issue do not settle anything since how one construes the facts is crucial, and this is determined by one's religious and moral values. Biomedical issues of most concern to Conservative thinkers are issues of human sexuality (e.g., fertility and homosexuality) as well as questions of the beginning and end of life (i.e., abortion and euthanasia). Conservative legal thinkers legitimize the consultation with science by insisting that Jewish law itself presupposes the existence of knowledge and morality independent of Jewish law.

Of all variants of modern Judaism, Modern Orthodoxy (in contradistinction from Ultra Orthodoxy) is most preoccupied in the dialogue between science and religion, precisely because on the surface the two may appear to be contradictory. Founded by Samson Raphael Hirsch (1808–1888) in Germany, Modern Orthodoxy was also a response to the challenges of modernity, even though it rejected the radical ritual changes of Reform Judaism or the historical approach of the positive-historical school, the ideological foundation of Conservative Judaism. For Hirsch, a "Torah-True Judaism" meant that the Torah is eternal and unchanged, but that Judaism must be informed about and selectively involved in the secular world. His slogan, "*Torah im Derekh Eretz*" (Torah combined with secular knowledge), became the institutional credo of Yeshiva College in New York City, which was founded in 1928 and became a university in 1946. This institution was committed to the synthesis of "Torah U-Mada" (Torah and science), although the precise meaning of this ideal is repeatedly questioned. The faculty and graduates of Yeshiva University publish essays about the interplay of science and religion in their academic magazines—*Tradition: A Journal of Orthodox Thought* and *The Journal of Halacha and Contemporary Society*—and even founded a magazine devoted solely to that issue: *The Torah U-Mada Journal*. Precisely because Orthodoxy understands Judaism as truth, it takes note of seemingly competing truth claims in science.

For Modern Orthodoxy the affirmation of the dialogue between science and Judaism is based on the following assumptions: first, Halachah is binding and all-encompassing and no aspect of human life is irrelevant to it, including science. Second, since halachic discourse exposes the true meaning of divine revelation, there can be no contradiction between what is true in science and what is true in Judaism. Third, scientific and technological advances can help resolve many practical details of religious practice, especially in matters that concern the human body. Medical ethics is thus a primary area in which a fruitful interaction between science and Judaism can take place.

Fourth, science is not the source of value, and science requires a framework of values whose authority is other than human. Judaism's moral values are absolute and immutable because they are revealed by God.

Orthodox scholars reject biblical criticism and treat the halachic tradition as an eternally valid legal system that has its internal mechanisms of self-interpretation. In terms of the doctrine of creation, Orthodox Jews, who tend to pursue the study of the natural sciences but shun the humanities and social sciences, argue, not without a tinge of apologetics, that the Big Bang theory validates even the details of biblical narrative of creation, although science still fails to explain why the world was created. That explanation is available only to the believing Jew who ascribes the creative act to God's will. In regard to bioethics, Orthodox jurists such as Rabbi J. David Bleich and Rabbi Immanuel Jakobovits, who are informed in contemporary medicine, bring their extensive knowledge of the halachic tradition to bear on a host of medical problems. These include dwarfism, transsexual surgery, egg donation, and implantation, Tay-Sachs disease, dental practices, skin grafting, organ transplantation, hazardous medical procedures, establishment of death, the treatment of human corpses, eugenics, sterilization, contraception, the proper conduct of physicians, gene therapy, and cloning technology. Though no medical issue is outside the scope of Halachah, it is the halachic corpus itself that defines the principles that enable the Modern Orthodox jurist to determine what is permissible. To the extent that this endeavor requires a theological justification, the model is found in medieval Jewish philosophy of Maimonides and his disciples. Ultra-Orthodox Jews, however, do not accept the Maimonidean synthesis, are not interested in accommodation to modern life, and take a literalist approach to Scripture. For them, science and Judaism belong to different realms and their truth-claims are of unequal epistemic value.

In sum, while there is no theological impediment to the study of nature in Judaism, there has been some unease about the pursuit of science in traditional Jewish society. Either because scientific knowledge originated outside Jewish society, or because scientific inquiry could divert Jews focusing exclusively on Torah, premodern Jewish culture harbored suspicion toward the study of nature, classified as "secular learning." In the Middle Ages, especially in Spain and Southern France, Jews cultivated the natural sciences and excelled in mathematics, astronomy, and medicine, but these achievements were overshadowed by the preoccupation with law and with Kabbalah in the early-modern period. In the modern period, the dialogue between science and religion has been configured in the context of Jewish social integration into Western society and the need to rethink the authority of Halachah. Reform Judaism, which champions full integration and denies the authority of the rabbis, takes for granted that Judaism is rational, and does not see science as a challenge to Judaism at all. Conservative Judaism, which promotes allegiance to the Jewish tradition along with admission that Halachah evolved over time, is aware of the challenge but considers scientific theories useful for a deeper understanding of Scripture and legal decision-making. Finally, modern Orthodoxy, which insists on the eternal validity of Halachah while being open to modern life, is most creative in attempting to respond to new scientific theories and technological advances. Most modern Jews, who define themselves religiously, and not only ethnically or culturally, regard scientific study of God's created world positively, while insisting that scientific means and ends be judged and/or complemented by Jewish religious and moral values.

See also JUDAISM, CONTEMPORARY ISSUES IN SCIENCE AND RELIGION; JUDAISM, HISTORY OF SCIENCE AND RELIGION, MEDIEVAL PERIOD; JUDAISM, HISTORY OF SCIENCE AND RELIGION, MODERN PERIOD; MAIMONIDES

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HAVA TIROSH-SAMUELSON

JUDAISM, CONTEMPORARY ISSUES IN SCIENCE AND RELIGION

Although the pace of the scientific inquiry has increased tremendously since 1800 and the hegemony with which scientific veracities shape culture has surely increased as well, for religious systems, texts, and communities, the challenges and questions posed by science are classic ones. Science as a theory and practice makes several claims: that the natural world has order, laws, and causality; that such order can be apprehended and explained by human beings; and that the manipulation of the nameable, quantifiable, and discernable elements of that natural and tangible world can be achieved to organize human social and cultural life.

Science and ethics in Judaism: discernment and discourse

In Jewish thought and tradition, this search for understanding, the discernment of order, and the reordering of the natural world are not only achievable, but a divinely commanded part of a larger imperative to heal and to repair the world. For Jewish philosophers, the freely entered Covenant that assigns these tasks to an elected people is what makes ethical norms possible (Hartman 1985). However, moral norms cannot be established without reference to a complex legal system that draws on centuries of case law and textual interpretation. For over two centuries, this system has been applied in reflection on the dilemmas of science and of modernity. Science, in particular natural science, has been wholeheartedly embraced as allowing the fullest understanding of the events and cases in the world in which the community practices its religion.

Unlike faith traditions that reify the natural world as essentially sacred and unchangeable, Jewish thought affirms the human ability to alter the natural world, seeing in this alteration the ability to create justice and healing as acts of faith and obligation. The relationship between Jewish thought and scientific understanding varies over different historical periods. In fact, the intellectual attention of Jewish tradition had been largely focused on the moral and social task rather than the actual achievements of science until well into the Enlightenment (H. Levine 1972; Samuelson 2001).

The structure of Jewish ethics and Halachah

Jewish ethical norms are established via a legal system called *Halachah.* (The root of this word in Hebrew is related to the word "to walk"; the same root is also found in Islamic law or *sharia.*) Bounded by this system of religio-legal behavior, the individual Jew, once past the age of thirteen (twelve for women), is responsible for the performance of *mitzvot* or divine commandments of activity and response to God and to the community. There are 613 such commandments in the traditional reckoning, a metaphorical number that stands for the completeness of obligation. Many commandments are concerned with the daily details of ritual and familial life, many are employed in the service of civil codes, and others set the perimeters of response to newly arising dilemmas, such as how to regard cloning, nuclear fission, and space travel. At stake in the system is not only whether the intended act is regarded as a prohibited, permissible, or exemplary activity, but how the activity ought to be carried out, using what criteria for assessment. Jewish ethics is a complex negotiation with procedural questions and substantive ones.

The first procedural question that the system of Jewish ethics addresses is the problem of how to achieve good ends in a nonteleological system. Judaism answers this in a way that is the unique hallmark of the method; it is a method that, while based in law, draws on a variety of sources both to create the cases for the law and to resist and query its assumptions. The basic procedure for the evaluation of norms is the mode of argumentation—commentary, debate, and discussion. Essentially casuistic, the halachic system uses the encounter with the Torah text, and the encounter with the other's encounter with the text, to create a continuous discursive community. Cases are raised to illustrate points of law and then to illustrate alternate interpretations of the law. Narrative, in a variety of literary forms (metaphor, allegory, historical reference, intertextual mirroring) called *aggadah,* are embedded in the text. While the details of the *aggadah* did not create binding laws, the form was used to grapple with and embellish the discussion of the details of the Halachah. The casuistic account attempts to decipher the particular and specific human ways the principle has been, or theoretically could be, applied. In fact, it is essential to remember that much of the case law turns on elaborate constructs that never happened, or could never be expected to happen, as well as actual cases that arose in community practice.

Judaism is both a deontological and a casuistic system, rooted in rules, duties, and normative conduct and concerned with motive and process. But it is unlike a purely deontological system because the real world, and the context and outcome of each case, count in their assessment. Judaism is a modified casuistic deontology. Consequences, once enacted, are reexamined and debated. The real world matters: knowledge of precedence, historicity, the tactile, and the theoretical all count in this system. Human reason is needed both to negotiate the system and to interpret intelligently the sensory natural world. Talmudic methodology was argument structured by text, history, and community. These three elements, and the use of reason to decipher them, modify the deontological method of Jewish ethics. It was *deontological* because it assumed Torah law as motivational, commanded, central, and binding; it was *casuistic* because it was also inductive and case (context) modified.

The central claim of Jewish ethics is that truth is found in the house of discursive study—the *bet midrash.* Such a public discourse is created when Jews argue, face to face, about the meaning and relevance of the narrative, symbols, and referents. Embedded in the problem are issues of context, causation, agency, norm, and assessment. Each of these issues must be addressed by whomever is describing whatever methodology of ethics they use, with the assumption that methodology in ethics involves not only a general theory of morality, authority, and value, but also "middle axioms," or the middle ground between general principles and the details of policy. James Childress and John Macquarrie, however, consider this a "misleading term" in the *Westminster Dictionary of Christian Ethics* (1967). Perhaps a better description would be a coinage: "middle processes." Methodology in any integral ethical system must address both the *why* and the *how* of a "right act" if it is to have coherency and if it can be used in the human hands and heart of the world, and Jewish ethics is no exception. Jewish ethics presumes public choices; it assumes community, human sociability, and embodied dailiness, and that ordinary human acts have a weight and meaning that ought to be the subject of urgent discourse.

A central question: Is there an ethics independent of Halachah?

The idea that rules and laws form the base of the system can be agreed on, yet the methodology of argumentation creates nuances of interpretation. Since about the mid-nineteenth century, four branches of Judaism have developed. All acknowledge the role of Halachah, but each gives it different weight in the setting of normative standards for their tradition. For the Orthodox Jew, Halachah is interpreted by his or her rabbi, who then consults with leading scholars if the issue is difficult, and that decision is considered halachically binding. For the Conservative Jew, Halachah has a strong voice in the determination of *din* (Judgment) by the rabbinic community. The Conservative *minhag* (custom) is determined by the community. Jewish law is then integrated with insights from the social sciences and Western philosophic norms in making a decision. For Reform Jews, the individual is autonomously responsible for his or her own choices, in light of the "tradition" and the primary ethical stance of the tradition. This entry will describe the traditional or *halachically* grounded position, although it is crucial to remember that among Jews there is considerable variance. It is arguable that, even for Jews not bound by its restraint, Halachah wields a strong methodological influence.

The central procedural question for all branches of Judaism stands in tension with the praxis. For example, the dilemma of the achievement of justice is *not* resolved, and the quest itself proves key to opening the method. The multivocity of the form itself insists on the questioning of the solidity of the text: To name as definitive one personal interpretation is a violation of the Talmudic method. For many of the proof texts there are countervailing premises and correspondent inimitable truths, and rabbinic decisors who defend differing positions.

Marvin Fox, writing in *Modern Jewish Ethics, Theory, and Practice* (1975), one of the central works in English on this topic, argued that the halachic system itself includes an accountability to a variety of sources. His insight was that the basic method incorporates science, philosophy, and natural reality into the traditional texts. The rabbis used exegesis and interpretation as the most important device to reconcile the basic and sacred text with the reality of exile, change, and science. Fox further noted that the incorporation of "external to Sinitic" sources was always a part of the discourse. He argued that Maimonides (c. 1135–1204) assumes math, astronomy, and "speculative realities" are better known by the Arabic world than by the rabbinic sages and that Jews need to "accept truth from any source." Fox noted Judah HaNasi's confession that, in some arguments, the Gentile sages "vanquished the sages of Israel." This was cited in the tradition as a case of how best evidence and best argument from whatever source ought to prevail.

Saadya Gaon made this point, according to Fox, even more forcefully by insisting that reason existed both prior to and after Sinai. Further, Fox noted that interpretation has always varied widely, even at the heart of basic texts (like the Moses story, the Ruth story, the view of the Nazarite vow, and the problem of creation itself). Additionally, he pointed to the flexibility of the *aggadah* as indicative of the freedom at the heart of Jewish method itself. Fox reminded us that tradition has each Jew at Sinai now and for eternal generations and noted the rabbinic *Midrash* that says each Jew hears the revelation through his or her own body and experience.

Rabbi Joseph Soleveitchik, the late leading contemporary halachist, wrote extensively regarding the relationship between the method of ethical discernment and the scientific method itself, finding in physics a way of understanding the structure of human understanding. He argued that physics and the theory of relativity teach that truth can be viewed from many perspectives, and that the universe is not a Newtonian machine, but a complex of related happenings. One's perspective, then, will determine the "true" view of the object. One can see a stream and note its beauty, its physical properties, or its ritual use, for example. All are "real" views of the same phenomena. Further, Soleveitchik understood that human perception is a function of the truth that each person perceives, as each person individually views the "real" from the perspective of a particular and chosen order. What is seen as actual is a chosen fact pattern based on a system of value and belief. Soleveitchik posited the notion that to be religious or to be scientific, while they may represent radically different worldviews, was not only to value the world differently, but to experience and to see the phenomena of the world differently as well. That notion was entirely consistent with the concept of truth understood as "plural truth," and it served to explain how specific events could be seen as miracles or a function of the events of the causative natural world.

Science: the epistemic questions

Scientific inquiry is based on the application of human observation and human reasoning to events in the observable world. As such, it might seem that science offers a primal threat to faith traditions due to the unseen and unprovable truth claims of faith. However, Jewish tradition has long been able to incorporate secular knowledge from medicine and science into ethical norms. New insights are evaluated as cases to be compared to historically precedential ones. Scientific insights and achievements can thus be incorporated. Hence, post-Darwinian writings reinterpreted the "six days of Creation" as occurring in "six periods," or six divine "days," and electricity became legally bound by the rules of the Sabbath by understanding it as a form of "fire-making." "Science" or secular knowledge in general was often used to represent "a vehicle for a certain cluster of liberal, democratic values" argued as central to Western, or American values, a metaphor for the use of objectivity, impartiality, and civic order (Holliger). The methods of science, the use of clinical trials and controls and the use of animal models were also strongly embraced by Jews. In general, Judaism makes the assumption that the order of nature is accessible to human reason, and that nature, while offering some suggestive models for human behavior, is not the source of moral authority.

While social conditions, exclusion from the developing academy, constraints on employment, and isolation in European ghettos left Jewish intellectuals behind in the development of science in the early modern period, the nineteenth and twentieth centuries were marked by an enthusiastic embrace of and a mastery of many fields of scientific inquiry.

Science: substantive questions

Astronomy and cosmology dominated early reflections in Jewish thought because of the importance in calculations of calendar holidays, and, as Hillel Levine notes, because of the rabbinic attention to time rather than space after the destruction of the Second Temple (Levine, p 856). Levine further remarks that Jews, in their capacity as traders between different Jewish communities, acted as interpreters of the insights from Islamic and renaissance Christian civilizations. Medicine, as a commanded obligation of Jewish communities, was often a venue for investigation in science. Jewish physicians were often called upon to assume the relatively high-risk activity of caring for the sick, in part because they had a access to the large armamentarium of knowledge. Scientific discovery came later to the large Jewish community. A complex interest in kabbalistic beliefs and rituals, a renewed emphasis on spirituality, and compelling disputes about how to resist persecution and about how to engage modernity politically or communally, dominated Jewish views on the "new science" of the Enlightenment in the sixteenth through the eighteenth centuries. To the extent that science was posited as opposed to faith, it was regarded in traditional communities as suspect. It is Levine's contention that Jews in that period did not view science as "universally valid, but simply as the source of religious persecution in a new key" (p. 860).

But the search for the truth grounds moral reasoning. By the nineteenth century, the truth claims of science had been well established. Descriptive science such as the cataloging of species, germ theory, and the use of instruments of observation were eagerly taken on by the Jewish intelligentsia. In the twentieth century, Jewish commentators turned their attention to the problems of intervention, prevention, and cure, as well as the search for origins. Finding little to prohibit basic research, and reasoning from principles that stressed stewardship and ordering of the natural world, Jews were easily able to reconcile new discoveries, supporting the sense not only that the natural world was knowable, but that it ought to be. It should be mentioned here, of course, that Nobel Prizes in the sciences and medicine have been won by Jews in numbers far greater then their presence in the world population.

Halachah, too, has advanced to address new science. Science disrupts categories of being. An essential premise of the method is that events are best understood by disassembly into knowable parts—ever smaller, ever more essential. For a halachic system, this offers an opportunity to renegotiate the borders of permissibility at each component piece, commodity, or event. Modern halachic authorities such as Orthodox rabbi Faitel Levine openly struggle with the challenge that new science brings to a textual tradition governed by law. Levine, a traditional rabbinic *poskim* (a rabbi to whom specific legal questions are directed) specializing in new technology, writes in *Halacha, Medical Science, and Technology* (1987): "Once reality was relatively constant, unchanging . . . in the objective world in which halachah operates . . . But things have changed. In today's world, reality itself is undergoing repeated, fundamental changes. Objects which have little in common with traditional objects are constantly produced . . . consequently, our contemporary world in evading the control of traditional terms and concepts. But Torah is eternal!"

Recent controversies in the field of reproductive health and genetic medicine have often dominated the debate between religious communities and scientific investigators. In these debates one can see how the concern for healing, the obligation to repair the world, and the view that human life is fully ensouled only in developmental stages, rather than at the moment of conception, has allowed for a robust acceptance of basic research in biological sciences.

The acts of practice in traditional Judaism revolved around two centralities. The first is study of text, and the second is commanded acts that create a just society. Central to Jewish texts is the recognition of the as yet unredeemed quality of the world—even the natural world as understood by science. Just as circumcision is one mark of the covenant, a mark of a human response to birth, and a refinement of the natural world, so too is the notion that advanced scientific inquiry is a part of *tikkun olam,* the mandate to be an active partner in the world's repair and perfection. In the world of suffering and injustice, much, although not all, of clinical and business scientific research can be understood as an opportunity to address this injustice. This justice consideration is made actual by a support for science, medical advance, and the freedom of inquiry, all ways that human work to perfect the world can be fully embraced. While texts warn of the possibility of hubris, and there are many texts that teach of the danger of confusing the quest for learning with the temptation to control, the struggle to understand and to interpret the covenantal relationship includes extending the duty to heal. In this way, Jewish thought has long turned to science as a critical way to lay the groundwork for the study and the repair of the world.

See also JUDAISM; JUDAISM, HISTORY OF SCIENCE AND RELIGION, MEDIEVAL PERIOD; JUDAISM, HISTORY OF SCIENCE AND RELIGION, MODERN PERIOD

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LAURIE ZOLOTH

JUDAISM, HISTORY OF SCIENCE AND RELIGION, MEDIEVAL PERIOD

Interest in science among medieval Jews, which began in the ninth century, was a consequence of the unprecedented rise of a scientific culture within Islamic civilization a century earlier. Traditionally, Jewish intellectual life was self-contained. It revolved around a canonic corpus of texts, notably the Talmud and the *midrash* in Hebrew and Aramaic; cultural goods existing beyond this corpus were considered as threatening "foreign sciences." But having adopted Arabic (or rather

Judeo-Arabic) as their cultural language, Jews became acquainted with the surrounding Arabic culture. This set in motion a process of reception, assimilation, and transmission of knowledge, leading to the constitution of the medieval Jewish rationalist culture, first in Arabic and then in Hebrew.

The first influential Jewish writers to discuss philosophy in Arabic were Saadia Gaon (882–942) in Baghdad, and Isaac Israeli (855–955) in Kairouan (present-day Tunisia). Both drew heavily on contemporary scientific theories and thereby introduced their Jewish readers to them, *ipso facto* also legitimizing them. In the next century, the center of gravity of the philosophic-scientific activity of Jews switched to Spain: Salomon Ibn Gavirol (c.1020–1057), the well-known poet, was followed by a number of scholars who wrote books on religious Jewish philosophy: Baya Ibn Paqudah (second half of the eleventh century), Juda ha-Levi (c.1075–1141), Joseph Ibn Zaddik (d.1149), Abraham Ibn Daud (c.1110—1180), and others. Beyond their great ideological differences, all these works naturally drew on contemporary scientific and philosophical theories, testifying that these theories were familiar to, and accepted by, the educated Jewish reader. These same works were translated into Hebrew a century or two later for the benefit of readers not knowing Arabic, thereby introducing Greek and Arabic science into the traditionalist communities of Southern France.

Maimonides

Moses Maimonides (1135–1204), the central medieval figure of both Jewish thought and Law, was born in Córdoba, Spain. Owing to persecutions by the Almohads, who forbade Jews or Christians to profess their religion openly, Maimonides left Córdoba and eventually arrived in Egypt, where he settled in the 1160s. Maimonides's two most important writings are the monumental *Mishne Torah,* a code of the Jewish law composed in Hebrew, and the *Guide for the Perplexed,* the major Jewish work of religious philosophy, written in Arabic. Maimonides possessed charisma, a natural, unquestioned authority accepted near and far. The opinions Maimonides expressed with respect to the value of the study of science and philosophy are therefore of crucial importance for an adequate understanding of the Jewish attitudes toward them from the thirteenth century onward.

The Aristotelian sciences and philosophy are an integral part of Maimonides's worldview. The *Mishenh Torah,* although a legal work, opens with a concise account of the Aristotelian cosmology, in which Maimonides indicates that the first commandment is to *know*—not believe—that there exists a First Being who endows with existence all beings. In the *Guide for the Perplexed,* scientific theories are woven into the very substance of most arguments. Maimonides also repeatedly states explicitly that the study of the sciences and of philosophy is strictly indispensable for a knowledge of God, which is the goal of human existence.

Maimonides regards a contradiction between the truths established by the philosophers (i.e., Arab Aristotelianism) and the Scriptures as an impossibility. He holds that the scientifically established tenets of Aristotelian philosophy being necessarily true, whatever statements in the Scriptures appear to be at variance with them must be interpreted so as to make the Scriptures conform. This means that whoever naïvely reads the Scriptures without the input of science and philosophy necessarily errs and ends up in heresy; only the student of Aristotle can correctly grasp the meaning of the Scriptures. For Maimonides, acquiring scientific knowledge is therefore a religious obligation: "listen to the truth from whoever says it," Maimonides repeatedly urged. Only reason, not tradition, was to determine which knowledge-claims were to be accepted within Judaism and which not. Maimonides thus deserves the credit for having opened the gates widely to the study of the "foreign sciences" within Judaism.

This statement must be qualified, however. For Maimonides, the study of the sciences is never an end in itself: It is always propaedeutic, preparing the student for something more noble, namely, the metaphysical knowledge of God. In this respect, Maimonides's stance differs fundamentally from that of the Muslim scientists and philosophers of his day, with whom he is often compared: Maimonides and his Muslim contemporaries construe the social role of the man of knowledge in very different terms.

The place that Maimonides assigns to science is limited also on the epistemological plane, for he sets severe limits on the possible bearing of the sciences. Maimonides thus argues that, contrary to what Aristotle himself believed, Aristotle did not succeed in demonstrating that the world was eternal. Maimonides also argues that upholders of creation *ex nihilo* have not been able to demonstrate their own claims either. For Maimonides, the question of the eternity of the world is thus undecidable (i.e., it cannot be scientifically decided). Maimonides then says that he himself opts for the thesis of creation, but for theological and social, not scientific, reasons. Thus, although Maimonides affirms that without science the Scriptures cannot be correctly understood, in the end he assigns to science a severely curtailed scope. Maimonides is thus fundamentally ambivalent about the role of science.

This ambiguity of Maimonides's message was exacerbated by the fact that Maimonides affirmed that his *Guide* was an "esoteric text," one comprising certain "secrets" that only the wise and learned reader would be able to uncover. Some readers took this statement as signaling that Maimonides's true beliefs were the opposite of those he ostensibly affirmed, and that in truth he held radical theses—notably that of the eternity of the world—which he did not wish to state openly. Some Maimonideans therefore found in the *Guide* messages that were the precise opposite of the literal messages.

Maimonides's philosophy was a decisive turning point: It legitimized the study of the Greek-Arabic sciences as a permissible, indeed, an obligatory activity. Still, at the same time, the scope of the sciences and their authority relative to that of the traditional disciplines was not defined unequivocally. This remained a subject of controversy for the centuries to come.

Transmission of science and philosophy into and Northern Spain and Southern France

The reception of science and philosophy within the Jewish communities of Northern Spain and Southern France, whose only cultural tongue was Hebrew, can usefully be divided into three phases, The first phase of the transmission began early in the twelfth century when Spanish scholars composed in Hebrew (or translated from Arabic) scientific works for Jews living north of the Pyrénées. During the first half of the twelfth century, Abraham bar Hiyya (died c. 1145) of Barcelona, a political leader and scholar who was very well versed in the sciences of his day, wrote a number of works summarizing the sciences in Hebrew. He offered basic courses in such immediately useful disciplines as practical geometry and astronomy, and also composed an encyclopedia affording "general culture" with no immediate practical utility. Also influential was the poet Abraham Ibn Ezra (1089–1164), who left Spain and traveled throughout France, Italy, and England, spreading his ideas and writings. In addition to his astronomical and astrological works, Ibn Ezra composed numerous Biblical commentaries that often invoked scientific, philosophical, and astrological notions. Ibn Ezra thereby suggested that these scientific theories were indispensable to uncover the true meaning of the Scriptures. Owing to the great popularity of these commentaries throughout Europe, they contributed much to the spread and legitimization of "Greek learning."

The second phrase of the process gathered momentum when, in the second half of the twelfth century, Andalusian Jewish scholars immersed in Arabic culture fled to Provence to escape the Almohad persecutions in Spain, enhancing considerably the process of translation into Hebrew of philosophical works. A number of erudite Jewish families settled in Provence during the late 1140s, bringing with them a culture that was altogether different from that of their brethren. Whereas the latter were absorbed in traditional, Talmudic learning, the immigrants were comfortable with Arabic poetry, literature, grammar, philosophy, and science. This led to a massive translation movement that was to last for some two centuries, during which the newcomers and their descendants rendered a rich body of literature from Arabic into Hebrew. The first translated works were mostly Jewish religious philosophy, but gradually works of general philosophy and science by pagan and Muslim writers were translated as well.

The third phrase began after the transmission process got a new and decisive impetus when Maimonides's writings, notably the Hebrew translation of the *Guide of the Perplexed* (1204), became influential in southern France. Jewish scholars imbued in Arabic culture composed a number of encyclopedic works with the aim of affording Jews who could read only Hebrew an overview of the sciences of the day. In parallel, scientific and philosophical works were translated systematically and professionally. Many of the translators were scholars belonging to the Tibbonid family: Yehudah Ibn Tibbon (c. 1120–1190); his son Samuel (1150–1230), the translator of the *Guide*; and Samuel's son Moses (c. 1240–1285). A number of other translators of scientific and philosophical texts were active too. Together, these scholars created the Jewish medieval philosophical-scientific bookshelf. This bookshelf includes the basic works of the exact sciences, beginning with Euclid (mathematics) and Ptolemy (astronomy), and numerous further mathematical and astronomical texts. It also comprises the basic works of the "qualitative" sciences (natural philosophy, biology, medicine, psychology, metaphysics, etc.). Most important in this respect are Averröes's systematized presentations of the Aristotelian doctrines, which became for the centuries to come the standard textbooks studied by Jewish scholars.

Assessment of scientific contributions of medieval Judaism

The introduction of these works of Greek and Arabic science into Judaism triggered a production of scientific works in Hebrew. This movement developed on the basis of texts available in Hebrew, for it was fairly (although not totally) isolated from the Latin scholastic university culture. Whereas, from a cultural point of view, this literature had great significance for Jewish intellectual life, it is not comparable in terms of originality and intrinsic importance qua science to the literature of medieval Arabic or Latin cultures. Astronomy is, however, a significant exception to this rule, and Jewish astronomers performed as well as (and occasionally better than) their contemporaries. The reason for this relative underdevelopment of medieval Hebrew science was arguably the social role that Maimonides had assigned to science as (merely) propaedeutic to the study of God. Two towering figures stand out as exceptions, however. Levi ben Gershom, or Gersonides (1288–1344), lived in Provence and wrote treatises on logic, mathematics, biblical exegesis, philosophy, and astronomy. In all these domains his contributions are eminently original, and the fact that he made numerous astronomical observations, using instruments he himself invented, must be particularly emphasized. Gersonides also had disciples who studied commentaries by Averröes with him and engaged in a written debate over purely scientific issues. The second figure is Hasdai Crescas (c. 1340–1412), who regarded Jewish adherence to the philosophical doctrines as a threat to the coherence and very existence of the community. This stance motivated Crescas toward a radical and highly insightful criticism of Aristotle's physics, which contributed to the rejection of Aristotelian philosophy during the Renaissance.

The introduction of the study of the sciences into the Jewish discourse did not go unchallenged. Even before Maimonides, Juda ha-Levi's *Kuzari* (1140) had criticized the philosophical project and contrasted the traditional "God of Abraham" with the philosophers' "God of Aristotle." Maimonides was vehemently attacked during his lifetime and the split, indeed the confrontation, between traditionalists and their adversaries over the study of the profane sciences was to continue during the centuries to come.

The thirteenth through the fifteenth centuries were the heyday of Hebrew science and of the rationalist Jewish culture in general. The rise of Kabbalah and the expulsion of the Jews from the Iberian peninsula in the 1490s were followed by a long period in which few Jews engaged in science or philosophy. The influential astronomer Abraham Zacut (late fifteenth century) is an exception. Still, here and there during the sixteenth and seventeenth centuries, some Ashkenazi rabbis in Germany and Poland continued to study the texts of the medieval Hebrew bookshelf. In the early eighteenth century, this dormant tradition was to bear new fruit and provide an important impetus to the *Haskalah* (Jewish enlightenment movement).

The cultural dimension of the reception of the sciences

The reception of science and philosophy within medieval Judaism had implications far beyond the mere sphere of science: It was nothing less than a theological upheaval. On the one hand, Maimonides's consequential synthesis legitimized the profane books as a source of knowledge, in addition to the traditional, sacred ones. On the other, the espousal of philosophy and science implied the acceptance of formerly unheard-of religious teachings: The Maimonidean God had very little in common with that of the Talmudists or the kabbalists, and, in addition, the intellectual activity of those who sought felicity (immortality of the soul) through philosophical knowledge was incommensurable with that of the fideists, for whom the Jews' afterlife depended solely on respecting the commandments and on erudition in the Talmud. In *Even Bohan* (*The Touchstone*), his satirical *maqâmah,* the early fourteenth-century scientist, translator and poet Qalonimos ben Qalonimos acutely noted: "Our Gods are as numerous as our towns." This upheaval thus implied a profound transformation of the definition of what it meant to be Jewish. The depth of the resulting fragmentation of Jewish society is perhaps comparable to that of the contemporary split of Judaism between Reformist, Conservative, and Orthodox.

See also JUDAISM; JUDAISM, CONTEMPORARY ISSUES IN SCIENCE AND RELIGION; JUDAISM, HISTORY OF SCIENCE AND RELIGION, MODERN PERIOD; MAIMONIDES

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GAD FREUDENTHAL

JUDAISM, HISTORY OF SCIENCE AND RELIGION, MODERN PERIOD

Moses Maimonides (1135–1204) wrote at the beginning of his comprehensive code of Jewish law, the *Mishneh Torah,* that the most fundamental commandment in Judaism is to believe in the creator deity, that no one can believe in the creator who does not understand creation, and to understand creation requires knowledge of the sciences, especially physics and astronomy. All medieval rabbis agreed that the proper worship of God involves commandments to do what is good and to believe what is true, and many of them agreed with Maimonides that scientific knowledge was a critical way to fulfill this religious obligation.

The early modern period (sixteenth to early nineteenth centuries)

As is clear from the example of religious scientists such as the astronomer Levi Ben Gershom (Gersonides, 1288–1344), Jews followed Maimonides's directives and made first-rate contributions to the advancement of scientific knowledge in the late middle ages. However, this consensus on the symbiosis of religion and science disappeared by the early modern period in European civilization. The level of Jewish studies in the sciences as of the middle of the fourteenth century was the peak of this development. Jews continued to study science, but there was little growth. While the level of Jewish achievements in the field of medicine remained high by comparison with the level of medical sciences in Christian Europe, the same cannot be said for the other sciences, even in the case of astronomy and physics.

From the sixteenth through the early nineteenth centuries the focus of Jewish spiritual practice turned away from natural philosophy (from science) towards a concentration on Jewish law (*Halachah*) and mysticism (*Kabbalah*). Still, there were many Jews who continued the Maimonidean tradition of scientific inquiry, especially in astronomy. Among their notable tractates were Judah Loew ben Bezalel's *Torat ha-Olah* (Prague, 1569), Mordecai ben Abraham Jaffe's Levush's *Or Yekarot* (Lubin, 1594), David Gans's *Nechmad ve-Na'im* (1613), Joseph Solomon Delmedigo's *Elim (Amsterdam, 1629),* Tobias Cohen's *Ma'aseh Turiyyah* (Venice, 1707/8), Jonathan ben Joseph from Ruchim's *Yeshu'ah be-Yisrael* (Frankfurt 1720), Raphael ha-Levi of Hannover's *Tekhumat ha-Shamayim* (Amsterdam, 1756), Israel ben Moses ha-Levi of Zamosc's *Netzach Yisrael* (Frankfurt am Oder, 1741), and Israel David ben Mordecai Jaffe-Margoliot's *Chazon Mo'ed* (Pressburg, 1843).

In general, by the second half of the sixteenth century Jewish students of astronomy were familiar with Copernicus's heliocentric theory. However, their attitudes to it were no more enlightened than that of the Roman Catholic Church, for in general all of these books were written as an apologetic defense of Maimonides's Aristotelian geocentric theory.

What happened that so dramatically altered the status of scientific learning in traditional Jewish communities between the twelfth and the sixteenth centuries? This is a question that scholars continue to debate. Critical factors include the increase of Jewish persecution in Christian Europe, which is conjoined to the increase of interest in Kabbalah and the decline of interest in the kind of natural philosophy that would develop into modern science.

The dramatic focus of this competition between legal studies, Kabbalah, and philosophic/scientific studies to win the hearts of intelligent Jews was the so-called "Maimonidean Controversies" that began in Europe during Maimonides's own lifetime, broke out again in Provence between 1230 and 1232, and spread from Provence into Christian Spain between 1300 and 1306. One of the important consequences of these controversies occurred in fifteenth-century Spain, where the curriculum of Jewish studies was revised to intensify the emphasis on law and all but eliminate the sciences as something identifiably "Jewish." (The critical exception to this generalization was the study of medicine and, as part of medicine, the study of what would become chemistry.) Whatever the causes, Jews who identified themselves primarily as Jews, as opposed to as members of a particular nation state, ceased to make any significant contributions to science. The same can also be said of Jews as human beings. However, this situation changed dramatically in the second half of the nineteenth century.

The modern period (late nineteenth and twentieth centuries)

When the philosopher Baruch Spinoza (1632–1677) was offered a professorship at the University of Heidelberg, he became, as far as we know, the first Jew ever to be offered a teaching position in a Christian European university. However, this was not a proper beginning, for Spinoza was a Dutch Jew who, as such, represented a most atypical Jewish community that had only recently emerged from its secret Jewish life as *conversos* in Spain. Moreover, Spinoza was a heretic. That a Jew could enter a Christian university if he left Judaism and became a Christian was not uncommon. However, Spinoza did not become a believing Christian even though he ceased to be a believing Jew. In the end, Spinoza did not accept the position in Heidelberg, and his thought had no significant impact on Jews until the late nineteenth century.

Excluding Spinoza, the first Jew to complete a doctorate in a Christian university was Joseph ben

Judah Chamitz, who earned a degree in philosophy and medicine from the University of Padua in 1624. Other Jews followed his example throughout western Europe after Joseph II of Austria issued his Edit of Toleration in 1782, after the Jews were emancipated in France in 1791, and after the Congress of Vienna created an union of German states to replace the Holy Roman Empire in 1815 and Italy was unified in 1861. The Jews were emancipated in Switzerland in 1866 and in Austria-Hungary in 1867. The Franco-Prussian War of 1870 to 1871 resulted in William I of Prussia becoming emperor of all the German states, and Germany became unified in 1871 under Otto von Bismarck. Two other, related critical events occurred in 1871: the new German constitution gave full rights to Jews, and the term anti-Semitism was used for the first time. The former event opened the doors to Jews throughout Germany, and from Germany throughout the Western world, from the late nineteenth through the early twentieth centuries. The latter event closed the doors of the university, culminating in the Nazi German attempt to "eliminate" Jews altogether.

The achievements of Jews as individuals (as citizens of their nation states and not especially as Jews) from the late nineteenth through the early twentieth centuries are impressive. By 1910, 2.5 percent of all full professors in Germany were Jewish, and 7.5 percent of all German students and 9.4 percent of all students (including foreigners) at Prussian universities were Jewish. Furthermore, by 1933 Jews constituted thirty percent of academic staff in natural sciences, over forty percent in medical faculties, and almost fifty percent of the mathematicians in German universities.

In general, the achievements of Jews as individuals in every academic field are even more dramatic. The originality that Jews failed to achieve in the early modern period was more than compensated for in late modern times. Notable Jewish astronomers include Hermann Goldschmidt (1802–1866, in France) who from 1852 to 1861 discovered fourteen asteroids between mars and Jupiter; Maurice Loewy (1857–1938, in Austria) who invented the Coudé telescope at the Paris Observatory; and Richard Prager (1883–1945, in Germany) who made major discoveries about variable stars at Berlin. In the United States, Frank Schlesinger (1871–1943) devised photographic methods for making parallax-determinations; Martin Schwarzchild (1912-1997) researched stellar evolution and designed satellite-born telescopes at Princeton University in New Jersey; and Herbert A. Friedman (1916–2000) studied outer-space spectroscopy at the U. S. Naval Research Laboratory in Washington, D.C.

Jewish involvement in chemistry was a natural outgrowth of earlier Jewish interest in medicine. In this respect it is notable that between 1905 and 2000 twenty-two Jews received the Nobel Prize in chemistry: Adolph Von Baeyer (1905), Henri Moissan (1906), Otto Wallach (1910), Richard Willstaetter (1915), Fritz Haber (1918), George Charles de Hevesy (1943), Melvin Calvin (1961), Max Ferdinand Perutz (1962), William Howard Stein (1972), Ilya Prigogine (1977), Herbert Charles Brown (1979), Paul Berg (1980), Walter Gilbert (1980), Ronald Hoffmann (1981), Aaron Klug (1982), Albert A. Hauptman (1985), Jerome Karle (1985), Dudley R. Herschbach (1986), Robert Huber (1988), Sidney Altman (1989), Rudolph Marcus (1992), and Alan J. Heeger (2000).

Jews even excelled in physics, which had ceased to be part of the Jewish curriculum in the early modern period. For example, during the twentieth century, Jews received thirty one Nobel prizes in physics: Albert Abraham Michelson (1907), Gabriel Lippmann (1908), Albert Einstein (1921), Niels Bohr (1922), James Franck (1925), Gustav Hertz (1925), Gustav Stern (1943), Isidor Issac Rabi (1944), Felix Bloch (1952), Max Born (1954), Igor Tamm (1958), Emilio Segre (1959), Donald A. Glaser (1960), Robert Hofstadter (1961), Lev Davidovich Landau (1962), Richard Phillips Feynman (1965), Julian Schwinger (1965), Murray Gell-Mann (1969), Dennis Gabor (1971), Brian David Josephson (1973), Benjamin Mottleson (1975), Burton Richter (1976), Arno Allan Penzias (1978), Peter L Kapitza (1978), Stephen Weinberg (1979), Sheldon Glashow (1979), Leon Lederman (1988), Melvin Schwartz (1988), Jack Steinberger (1988), Jerome Friedman (1990), and Martin Perl (1995).

The works of these physicists include: the perfection of the electromagnetic theory of radiation; quantum theory and its experimental confirmation; relativity concepts and their universal impact; atomic structure and its implication for electronics; and nuclear physics with its applications and implications for the study of high energy particles. Of these Jewish physicists, the most famous is Albert Einstein (1879–1955), who is especially known for his work on relativity theory. Many of the mathematicians who provided the foundation for Einstein's contributions to physics were also Jews. Of special note were Karl Gustav Jacob Jacobi (1804–1851) for his work on elliptic functions, Herman Minkowski (1864–1909) for his work on four dimensional space, and Tullio Levi-Civitá (1873–1941) for fundamental mathematics of relativity theory.

The least surprising area of Jewish excellence in science was medicine, since this was the one scientific subject Jews continued to study into the modern period in their traditional Jewish community schools. It is the area of scientific research whose application to Judaism is most evident, since it raises any number of questions concerning morality and Jewish law. For example, what is the role of sex in marriage independent of reproduction? Under Jewish law are any of the modern methods of treating infertility (including cloning, artificial insemination, and the use of surrogate mothers) permissible? The same questions apply to applications of genetic engineering and screening. Conversely, are any of the ways of preventing pregnancy (especially contraception, sterilization, and abortion) permissible? Furthermore, as modern science impacts on Jewish law and ethics with respect to life, it has implications for ways of dying, including questions about assisted suicide, cremation, autopsies, and organ donations. Finally, modern medicine raises questions for social ethics, from issues about a fair distribution of health care to issues about cosmetics (tattooing, body piercing, and cosmetic surgery).

By the middle of the seventeenth century European medical schools (notably in Germany, Poland, and Russia) began to admit Jews. One of the first was the University of Frankfurt on the Oder in Germany. One of its first students was Tobias ben Moses Cohen of Metz. Although he did not complete his studies there, he received his M.D. degree later from the University of Padua. Eventually he became a court physician to five successive sultans in Constantinople. Among the notable Jewish physicians of the eighteenth century were Marcus Eliezer Bloch in Berlin and Gumpertz Levison in England and Sweden, as well as Elias Henschel, who was a pioneer of modern obstetrics.

Jewish involvement in medical practice and research grew exponentially after the 1782 Edit of Tolerance in Austria. Still Jews tended to be held back, rarely rising academically beyond the titular professorial position of *privatdocent.* Jews tended to prefer new fields that were less attractive to non-Jewish competitors. An example is the pioneering work of Moritz Kaposi, Isador Neumann, and Heinrich Auspits in dermatology-venereology in Austria. In Germany dermatology came to be known as *Judenhaut* (Jews' skin). German specialists in this study included Paul Unna, Oskar Lassar, and Josef Jadassohn, and in Switzerland, Bruno Bloch.

Jews tended to dominate biochemistry, immunology, psychiatry, heatology, histology, and microscopic pathology. Among the leaders of microscopy were Ludwig Traube; of neuropathology is Moritz Romberg; and of neurology were Leopold Auerbach, Ludwig Edinger, and Hermann Oppenheim. In the twentieth century Jews entered freely into all fields of medicine and made major contributions to them, especially chemotherapy, immunology, hematology, heart disease research, lung and kidney disease research, gastroenterology, dermatology, pediatrics, surgery, obstetrics, gynecology, radiology, pathology, public health, and medical education.

In this respect it is notable that between 1908 and 1995, forty-four Jews received the Nobel Prize in medicine: Elie Metchnikoff (1908), Paul Erlich (1908), Robert Barany (1914), Otto Meyerhof (1922), Karl Landsteiner (1930), Otto Warburg (1931), Otto Loewi (1936), Joseph Erlanger (1944), Herbert Spencer Gasser (1944), Ernst Boris Chain (1945), Hermann Joseph Muller (1946), Tadeus Reichstein (1950), Selman Abraham Waksman (1952), Hans Krebs (1953), Fritz Albert Lipmann (1953), Joshua Lederberg (1958), Arthur Kornberg (1959), Konrad Bloch (1964), Francois Jacob (1965), Andre Lewoff (1965), George Wald (1967), Marshall W. Nirenberg (1968), Salvador Luria (1969), Julius Axelrod (1970), Sir Bernard Katz (1970), Gerald Maurice Edelman (1972), David Baltimore (1975), Howard Martin Temin (1975), Baruch S. Blumberg (1976), Rosalyn Sussman Yalow (1977), Daniel Nathans (1978), Baruj Benacerraf (1980), Cesar Milstein (1984), Michael Stuart Brown (1985), Joseph L. Goldstein (1985), Stanley Cohen [& Rita Levi Montalcini] (1986), Gertrude Elion (1988), Harold Varmus (1989), Erwin Neher (1991), Bert

Sakmann (1991), Richard J. Roberts (1993), Phillip Sharp (1993), Alfred Gilman (1994), and Edward B. Lewis (1995)

Of special importance within the discipline of medicine is psychology, within psychology is psychiatry, and within psychiatry is the work of Sigmund Freud (1856–1939) and his followers in psychoanalysis. As psychology emerged at the end of the nineteenth century, there were few Jews involved, G. F. Heymans at Louvain in Belgium being a notable exception. Modern psychiatry began with the work of Phillipe Pinel in France after the French revolution. The first Jewish psychiatrists to join this movement were Cesare Lombroso and Hippolyte Bernheim. Freud's own study began as an observer of Bernheim's work with hypnosis on mental patients. Freud published *Interpretation of Dreams* in 1900. Those initially associated with psychoanalysis in Freud's "inner circle" included the Jews Sandor Ferenczi, Karl Abraham, Max Eitingon, Otto Rank, and Hans Sachs. Most notable among those who followed Freud were Alfred Adler, Hans Sachs, Paul Federn, Theodor Reik, Helene Deutsch, Melanie Klein, and Freud's daughter Anna. Leading psychiatrists in the United States included Erik Homberber Erikson, Margarert Mahler, Leo Kanner, Lauretta Bender, Moritz Tramer, Paul Schilder, Beata Rank, and Rene Spitz.

Jewish science

One must be careful to distinguish the role of Jews in modern science as individuals from their role as Jews. Jews have been scientists in the modern period not as members of a Jewish community (as they were in the Middle Ages) but as free citizens in secular nation states. The schools where they studied, did research, published, and taught were sponsored by the secular state and not by any agency of the Jewish community. Is it legitimate to ask about these Jews whether or not their being Jewish in any way contributed to their science? Those most likely to give an affirmative answer to this question would be anti-Semites, especially those who dominated German culture in the 1930s and 1940s. Certainly most of these scientists themselves would make a sharp distinction between who they are as Jews (if anything) and who they are as scientists.

The most obvious names that people associate with Jews are Baruch Spinoza, Karl Marx, Henri Bergson, Albert Einstein, and Sigmund Freud. All five would have strongly denied that their Jewish ethnic identity had any bearing on their contributions to science. Spinoza was a product of a *converso* community, and furthermore, he was excommunicated; the excommunication did not seem to matter much to him, for he could live as easily among his Christian friends as he had lived in a Jewish community. Karl Heinrich Marx (1818–1883) can hardly be called Jewish at all. His father converted with his children to Christianity in 1824 (when Karl six years old). The case is almost the same with Henri Louis Bergson (1859–1941). He was raised in Paris by a father from Warsaw and mother from England, and Henri himself did the best that he could to conceal his upbringing, including the fact that he was Jewish.

There are many other Jews who could be listed in the category of those whose Jewish identity, even on cultural terms, was so tenuous that to call them "Jewish" is seriously misleading. Notable in this category are the sociologist Emile Durkheim (1859–1917) and the philosopher Edmund Husserl (1859–1938). Others include Karl Gustav Jacob Jacobi (1801–1851), who developed the generalization of Hamilton's theory in mechanics, and Georg Cantor (1845–1910), who made major contributions to the theory of the functions of real numbers. Felix Klein (1849–1925), who in 1882 published a paper on Riemann's theory of algebraic functions, developed the *Erlangen program.* which classified geometries in mathematical group theory. Ferdinand Cohn (1828–1898) identified several bacteria as agents of disease. Eugen Goldstein (1850–1930), together with Cromwell Varley (1828–1883), developed the leading hypothesis (waive interpretation) of the nature of cathode radiation. Finally, Paul Ehrlich (1854–1915) created chemotherapy.

The only notable modern Jewish scientist who understood his major work to be specifically Jewish was Hermann Cohen (1848–1918). Cohen is known primarily as a leading German philosopher of the neo-Kantian Marburg School and as a theologian of Reform Judaism. However, his career began as a philosopher of mathematics with the 1883 publication of his *Das Prinzip der infinitesimal methode und seine Geschichte* (The Principle of the infinitesimal method and its History), in which he developed an account of the meaning of differentiation and integration in calculus that served later as the foundation of his Marburg philosophy and his liberal Jewish theology. Cohen's colleague Paul Natorp (1854–1924) and his first pupil Ernst Cassirer (1874–1945) were both distinguished Jewish philosophers in the first half of the twentieth century. Both were oppressed for being Jewish and both shared the widespread view, in opposition to Hermann Cohen, that their Jewish identity was a sheer accident, of no relevance to their work as intellectuals.

The most interesting scientist in this respect was Albert Einstein (1879–1955). Jewishness played an important part in his life in terms of secular politics because he was a lifelong Zionist who was offered the first presidency of the modern secular state of Israel. Similarly, religious belief of some sort seemed to play a role in his speculations as a scientist. However, the role of religion in his life was always a private form of religiosity that he consciously dissociated from any traditional or conservative form of historical rabbinic Judaism. To the extent that Einstein was religious it was more like the religion of Spinoza, whose work he first read in 1920, when he was already forty-one years old.

The religion of Einstein was a religion that identified the highest form of divine worship with the uncompromising pursuit of the truth about the universe in general. Einstein identified this religious quest with Spinoza, who arrived at his distinctive conception of science as worship through his study of the Jewish philosophy of Maimonides. So we end where we began—with a symbiosis of science and religion, one that was clearly Jewish and religious in the medieval period and became increasingly universalist and secular in the modern period.

See also EINSTEIN, ALBERT; JUDAISM; JUDAISM, CONTEMPORARY ISSUES IN SCIENCE AND RELIGION; JUDAISM, HISTORY OF SCIENCE AND RELIGION, MEDIEVAL PERIOD; MAIMONIDES

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NORBERT M. SAMUELSON

K

KANT, IMMANUEL

Immanuel Kant, it is said, never traveled more than fifty miles from his native city of Königsberg in East Prussia. Nevertheless, there are few thinkers who have had as wide an influence as Kant in the history of Western thought. His importance for discussions about science and religion stems from his reasoned defense of the position that religion and science should be kept clearly separated from one another.

Life and writings

Born in 1724, Kant was the son of humble pietistic parents who wished for him to have an education. At sixteen he entered the University of Königsberg, where he studied Christian Wolff's interpretation of Gottfried Wilhelm von Leibniz's (1646–1716) philosophy. Kant's encounter with Isaac Newton's (1642–1727) work during his student years encouraged in him an independent attitude toward Leibniz's thought, with the additional result that he developed a profound interest in the natural sciences. When his father died during his university training, Kant left the university and served as a tutor in private families near Königsberg between 1748 and 1754. After returning to the university he completed a thesis in June of 1755 and, on finishing a second thesis in September, was granted permission to lecture. Prior to the age of thirty-six, Kant's writings dealt primarily, although not exclusively, with the natural sciences. His most famous work from this period, the *Universal Natural History and Theory of the Heavens,* was published in 1755 and contained Kant's ideas on the how a cosmos subject to Newton's laws of motion might have formed.

After Kant received a professorship in logic and metaphysics at Königsberg in 1770 it took some time before his writings reflected the turn his appointment marked from a precritical stance to what he himself labeled critical philosophy. Once Kant began publishing, the works came thick and fast. The first edition of his most famous book, the *Critique of Pure Reason,* did not appear until 1781. When it did so it was largely misunderstood, moving Kant to restate its main arguments two years later in his *Prolegomena to Every Future Metaphysics.* He also expanded the *Critique* in a second edition in 1787, and in the following year he published the first of two new critiques, the *Critique of Practical Reason.* This second critique picked up on a concern with moral philosophy Kant had initially addressed in another work from the 1780s. The *Critique of Judgment,* which appeared in 1790, dealt with reasoning about the realms of the aesthetic and the purposeful. Earlier in 1786 Kant returned to his reflections on science and its methods in a work entitled *The Metaphysical Foundations of Natural Science.* Finally, his *Religion Within the Boundaries of Pure Reason,* which appeared in 1793, provoked King Frederick William II to forbid him from publishing anything more on religion, a mandate he honored until the king's death in 1797. Kant died February 12, 1804.

Impact on science and religion discussion

Kant's impact on the subject of natural science and religion is best understood in his relation to the

Scottish thinker David Hume (1711–1776), whom Kant claimed awakened him from his dogmatic slumber. Exactly when this was to have occurred is unclear; however, among other things Hume represented for Kant the possibility that the use of reason in fact undermined the essential truths of religion, morality, and common sense. Kant faced squarely Hume's skepticism about causality and other conclusions of common sense that haunted the thinkers of the late eighteenth century. The fear was that if Hume's reasoning was correct about these matters, then how was one to retain one's belief in God? As Kant's contemporary Friedrich Jacobi (1743–1819) put it, "Nothing frightens man so much, nothing darkens his mind to such a degree as when God disappears from nature … when purpose, wisdom, and goodness no longer seem to reign in nature, but only a blind necessity of dumb chance."

In *Dialogues Concerning Natural Religion* (1779) Hume exposed the inadequacy where the relationship of God to nature was concerned of both classical metaphysical rationalism, in which one reasoned from principles accepted apart from or before experience (a priori), and empiricism, where reasoning was undertaken only after one experienced the world (a posteriori). In the *Critique of Pure Reason,* Kant attempted to forge a new path between both rationalism and empiricism by introducing what he called in the preface to the second edition a "Copernican" viewpoint in philosophy. The astronomer Nicolaus Copernicus (1483–1543) had shown that the way to think about the relationship of the earth and the sun was to reverse their traditional roles. Kant demanded that to understand the relationship of the world of experience and the mind one must also reverse the way in which roles were traditionally assigned. It is not that the mind is shaped by experience of the world (empiricism); rather, the world of experience is shaped by "categories" associated with the mind's operation. But in shaping our experience of the world the categories themselves prescribe only the structure for objects of possible experience (not the content of actual experience, as in metaphysical rationalism). Human minds dictate in advance, for example, that experience can only be apprehended in accordance with causal relationships between events, but they cannot determine prior to a person's experiencing the world which specific causal relationships actually obtain. Without content supplied by sense experience, the mind, even equipped as it is by its categories, would still be blind. But without the ordering impact of the categories, experience would be chaos. This is why Kant said at the beginning of the introduction to the *Critique* that "although all our knowledge begins with experience, it does not follow that it all arises out of experience."

This middle way contained important implications for the understanding of scientific knowledge. If the mind contributes in a formative way to the manner in which people experience the world, then they can no longer claim that the world they experience is necessarily the world that exists apart from the mind. Regularities in one's experience of the world, even those so repetitious as to earn the label of scientific laws, cannot be known as regularities in nature that one discovers; rather, they bear the touch of one's mind. People are, as Kant says in his *Prolegomena to Every Future Metaphysics,* "lawgivers of reason." Scientific knowledge, then, refers to the world of experience, the world of phenomena apprehended with the senses, not to a reality lying behind human experience. Gone is the possibility of conceiving truth as the correspondence of one's ideas to the way things are, a common conception of many scientists. One cannot be sure of the way things are, so there is no possibility of checking that against one's ideas.

If Kant's critique of reason introduced a radical limitation of what could be known, he was adamant that there was a realm that lay beyond cognition. "I have therefore found it necessary to deny *knowledge* in order to make room for *faith,*" he wrote in the preface to the second edition of the *Critique.* The object of faith, however, could not by definition be articulated or expressed in terms of knowledge. Religion for Kant did not and could not have to do with cognitive propositions about nature. In his 1793 book, *Religion within the Boundaries of Reason Alone,* he made clear that he accepted Hume's negative conclusions about the so-called argument from design, according to which one reasoned from evidence of design in the world to the existence of a designer. Religion did not commence with nor have to do with one's knowledge of the world. Religion had to do with the purity of one's heart. To be religious is to view one's duties as if they are divine commands. It should be noted that Kant's religious stance was purely intellectual. In spite of the fact that his philosophy made room for the possibility of eternal life, it was clear to those close to him that he scoffed at prayer and other religious practices and that he had no faith in a personal God.

Kant's position, then, radically separated science from religion, as if the two subjects contained no common ground. It took some time for this position to gain a hearing since in the Romantic period, which dominated in the first decades of the nineteenth century, there was great dissatisfaction with Kant's severe restriction of reason's scope to the realm of phenomena. Even one of the earliest neo-Kantian thinkers from this era, Jakob Fries (1773–1843), added *Ahndung* (aesthetic sense) to knowledge and faith as a third possible way in which people may relate to that which exists outside of them. Fries believed that through aesthetic sense people could intimate the infinite that was present in the finite.

It was not until the neo-Kantian revival of the late nineteenth century that Kant's radical separation of science from religion emerged in earnest. In the works of the Marburg theologian Wilhelm Herrmann (1846–1922), composed during the heyday of debates about biological evolution, one recognizes the attempt to cede to natural science the freedom to investigate natural phenomena without restriction while at the same time stressing religion's right to address questions of value and right. If religion must surrender nature to natural science, natural science, in turn, must along with religion renounce any claim to have arrived at metaphysical reality. Religion becomes morality while science becomes *Naturbeherrschung,* mastery of the world.

In the twentieth century the separation of natural science and religion continued to mark much of German theology, especially the works of well-known existential theologians who wrote in the decades following World War I. Most recently something of a Kantian position on the relationship between science and religion has been advocated by the noted American paleontologist Stephen Jay Gould (1941–2000) who, without ever naming Kant, introduced the notion of non-overlapping *magisteria* (NOMA) as a means of dealing with the realities of science, which is concerned with the factual construction of nature, and religion, which concerns itself with moral issues about the value and meaning of life. Gould acknowledge more than classical neo-Kantians, however, that while magisteria do not overlap, they are everywhere interlaced in a complex manner that often makes it extremely challenging to keep the two separate. Critics of the Kantian position maintain that in practice it is impossible to retain a rigid separation of science and religion.

See also METAPHYSICS; MORALITY; NATURAL THEOLOGY

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FREDERICK GREGORY

KARMA

Hinduism has many different definitions of karma, some making karma appear quite deterministic. A clear classical description is found in the *Yoga Sutras* of Patanjali (c. 200 B.C.E.–c. 200 C.E.) (sutras II: 12–14 and IV: 7–9). This description has been widely influential and makes room for free will. Every time one does an action or thinks a thought, a memory trace or karmic seed is laid down in one's unconscious. There it waits for circumstances conducive to it sprouting forth as an impulse or predisposition to do the same action or think the same thought again. This impulse is not mechanistic in nature, rather, it simply predisposes a person to do an action or think a thought. Through the use of free choice one decides either to go with the karmic impulse, in which case it is reinforced and strengthened, or to say "no" and negate it, in which case its strength is diminished until it is removed from the unconscious. Karmas can be either good or bad as defined by Hindu scripture. Good actions and thoughts lay down good karmic traces in the unconscious for the predisposing of future good karmic impulses. Evil actions or thoughts do the reverse. Karmic impulses do not disappear at death but are carried forward into the next life as one is reborn (*samsara*).

See also DETERMINISM; HINDUISM

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HAROLD COWARD

KENOSIS

Literally "emptying" in Greek, kenosis is a theological notion signifying the Christian belief that in the life and death of Jesus of Nazareth God empties out the divine selfhood in humble self-giving love to the world. This interpretation of deity has been inspired especially by reflection on the life and crucifixion of Jesus in whom Christians believe the fullness of God resides. In a letter to the Philippians, St. Paul cites an early Christian hymn that pictured Jesus as being "in the form of God," yet as one who forsook this lofty status and became a "slave" (Phil 2:5-11). Through the humiliation of being crucified, Jesus emptied *(ekenosen)* himself completely; for this reason, Philippians continues, "at the name of Jesus every knee should bow" Here Lordship somehow coincides with absolute self-emptying love.

Subsequent theological reflection has often, though not always or consistently, interpreted the text of Philippians to imply that in Jesus the very being of God is what is "emptied out." At times theologies have even gone to the extreme of interpreting the notion of kenosis to mean that God, in pouring out the divine substance, literally ceases to be God. The more accepted view, however, is that in God's self-abandoning incarnation in Jesus, who for Christians became the crucified and risen Christ, the ultimate ground and sustainer of the universe is revealed decisively as absolute selflessness and limitless compassion (co-suffering).

The image of a self-empting God in Christian tradition

This biblically inspired picture of a God who from all eternity foregoes any crudely domineering power in order to relate intimately to the created world has emerged more conspicuously than ever in contemporary theological reflection on the roots of Christian faith. While the image of God as self-emptying love has always been present in Christian tradition, it has often been subordinated to pictures of God as potentate, designer, or even dictator. However, to a theology that views the crucified Christ as part of the revelation of reality's underlying depths, it would seem that God renounces any claims to coercive omnipotence. It is to this God of actual religious experience, rather than to philosophically abstract portraits of deity, that an increasing number of theologians today hope to connect their conversations with science, and especially with evolutionary biology.

The theme of God's self-humbling has been present, though often nearly invisible, from the very beginnings of Christian tradition. However, in the nineteenth and twentieth centuries it began to emerge more explicitly. The theme of the "descent of God" can be found in many early Christian writers, and it is present in Martin Luther's (1483–1546) focus on the crucified God. Later it breaks out in the German philosopher George Friedrich Hegel's (1770–1831) interpretation of the divine incarnation. But it began to become a more prominent feature of Christian theology especially in the late nineteenth century and increasingly throughout the twentieth century. German theologian Dietrich Bonhoeffer wrote from prison, prior to his execution by the Nazis in 1943, that only a "weak" God could be truly effective in the world. His ideas, though undeveloped, became an important stimulus to the contemporary recovery of a kenotic theology. Likewise, British mathematician and philosopher Alfred North Whitehead (1861–1947) and process theologians have emphasized that God is a "fellow sufferer" who participates in the world's struggle and pain.

Thus for many contemporary Christian thinkers the image of a self-emptying, fully relational God seems to lie at the heart of a religiously coherent and pastorally acceptable theology. God's self-emptying is the underlying dynamism of the doctrine of the Trinity, which the Swiss theologian Karl Barth (1886–1968) held to be the distinguishing content of Christian revelation. The Roman Catholic theologian Karl Rahner (1904–1984) insisted that the primary message of Christian faith is the self-emptying of God. In Section 93 of his 1998 encyclical *Fides et Ratio* (Faith and Reason) Pope John Paul II stated that "the prime commitment of theology is seen to be the understanding of God's kenosis, a grand and mysterious truth for the human mind, which finds it inconceivable that suffering and death can express a love which gives itself and seeks nothing in return."

A self-emptying God as explanation for the creation and evolution of the universe

For some theologians the idea of a self-emptying God allows us to explain in an ultimate way, and in a manner that does not compete or interfere with scientific explanation, both the creation and the evolution of the cosmos and life. Uniting the idea of kenosis with Jewish cabalistic reflections, the Protestant theologian Jürgen Moltmann (b. 1926), for example, speculates in *God in Creation* (1985) that

> God "withdraws himself from himself to himself" in order to make creation possible. His creative activity outwards is preceded by this humble divine self-restriction. In this sense God's self-humiliation does not begin merely with creation, inasmuch as God commits himself to this world: it begins beforehand, and is the presupposition that makes creation possible. God's creative love is grounded in his humble, self-humiliating love. This self-restricting love is the beginning of that self-emptying of God that Philippians 2 sees as the divine mystery of the Messiah. Even in order to create heaven and earth, God emptied himself of all his all-plenishing [i.e., pervasive] omnipotence, and as Creator took upon himself the form of a servant. (p. 88)

Today, especially in discussions of religion and evolution, reflection on the idea of divine kenosis allows theologians to embrace the scientific picture of life without reservation. Emergent complexity, chaos, and nature's generically self-organizing tendencies fit more comfortably a universe grounded less in coercive power than nurturing love that allows the universe some degree of self-creativity. After all, it is in the very nature of self-sacrificing, kenotic love to long for the freedom and self-determination of the beloved. We may assume, then, that an infinitely self-emptying divine love would will that the created universe become something "other" than God. God could not be said to love unreservedly a universe that is not allowed to be distinct from the divine. Since kenotic love requires an "other," any conceivable creator who refused to risk allowing the world to be, at least to some degree, independent of God could not truly love it.

So, according to this line of theological speculation, it is because God is infinite self-emptying love that the universe is not constituted as perfect and complete at the beginning in one instantaneous act of divine magicianship. It is because a kenotic God wills the otherness of the world that it is not frozen into finished perfection from the moment of its origins, but is invited to emerge in patterns of self-organization that contemporary science has begun to notice so clearly.

To those who follow a kenotic theology any conceivable world must likewise allow for the kind of spontaneity that occurs in biological evolution. Any universe grounded in a divine kenotic love must possess a vein of indeterminacy from the moment of its most primitive physical origins. In the light of the divine kenosis it would not be surprising, then, to discover that the cosmos is not fixed in an immobile pattern of eternal sameness, but that it always has an inherent openness to novel and unpredictable outcomes. In the light of a kenotic understanding of the creator, it makes good theological sense that modern physics has disclosed a domain of "uncertainty" or indeterminacy in the elusive realm of subatomic energy events. It is consonant also with the notion of a kenotic deity that evolutionary biologists would encounter another kind of indeterminacy in the "accidental," undirected genetic mutations and many other contingencies of natural history that allow for the serendipitous emergence of life's prodigious variety. And, finally, the fact that humans apprehend in their own subjectivity an undeniable capacity for free choice appears especially consistent with the belief that the cosmos to which they are linked is rooted in a self-emptying principle of being intent upon the emergence of what is truly and deeply "other" than itself. A universe of emergent evolution is more or less what should be expected when people begin reflecting on nature with a belief in the kenotic nature of ultimate reality.

The seemingly aimless meandering of biological evolution may be incompatible with a divine designer, but not with a creative power that takes the form of defenseless love. If the deity were powerful only in the vulgar sense of having the capacity to overwhelm, then evolution might be theologically troubling. But a divine power that manifests itself in infinite self-giving love does not manipulate that which it enfolds. According to advocates of a kenotic theology, therefore, the unqualified religious claim that God is primarily a "designer" would be quite problematic. A designing deity could not permit the world any real independence. A kenotic understanding of divine creation, on the other hand, would allow that life and eventually mind may blossom indeterminately, and over a long period of time, in a universe that is in some sense self-creative from the outset. A kenotic deity would be the ultimate source of the possibilities for novel patterning made available to an evolving cosmos, but in such a way as to allow for a great measure of spontaneity in the evolution of life, mind, and freedom.

See also CHRISTOLOGY; EVOLUTION, THEOLOGY OF; WHITEHEAD, ALFRED NORTH

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JOHN HAUGHT

L

LAMARCKISM

Jean-Baptiste Pierre Antoine de Monet de Lamarck was born in Picardy, France, on August 1, 1744. He received a Jesuit education at Amiens and briefly pursued a military career before turning to science. Lamarck's interests ranged widely from natural history to meteorology, and with the reorganization of the Jardin du Roi into the Muséum d'Histoire Naturelle in 1793, he was appointed to the professorship of invertebrates. Lamarck's central concern, reflecting his Enlightenment values, was to present a thoroughly naturalistic and developmental account of all aspects of the natural world. His developmental geology followed uniformitarian principles, and his deism rendered irrelevant the optimism of natural theology and dissolved the distinction between humans and other animals. Lamarck believed that "life" is a force imposed on the universe by the creator, but he rejected any idea of a plan for the development of species. His early interest in botanical classification led to his conversion to a transformationist position after 1800, allowing him to explain a wide range of biological phenomena in one coherent system. Lamarck died in relative obscurity on December 18, 1829. His most influential works were his *Hydrogéologie* (1802), *Recherches sur l'organisation des corps vivants* (1802), *Philosophie zoologique* (1809), and *Histoire naturelle des animaux sans vertèbres* (1815–1822).

Although Lamarck himself founded no school of thought, his ideas became a standard point of reference and controversy during the century that followed. His failure to develop a convincing theory of the transmutation of species—in an era increasingly favorable to biological mutability—can be traced to his inability to articulate a credible mechanism for such change. He rejected the idea of species extinction, and evolution through the natural selective pressures never occurred to him. Lamarck's own theory about the transmission of acquired traits from parents to offspring lacked empirical support, and he seems not to have appreciated the significance of biogeography or the fossil record offered by paleontology for developing a complete evolutionary account of life. His posthumous reputation suffered substantially from the campaign of Georges Cuvier (1769–1832) against the insufficiencies of his theory of the inheritance of acquired characteristics. Nevertheless, Lamarck played a seminal role in broaching the basic idea of species change and in supporting it with a justification that rivaled natural selection in plausibility until the integration of Mendelian genetics with the theory of Charles Darwin (1809–1882) after 1900.

Neo-Lamarckism was a late-nineteenth-century movement with variants in France, Britain, and North America. Following the publication Darwin's *Origin of Species* (1859), naturalists who were skeptical of Darwin's insistence on natural selection drew upon Lamarck's theory to elaborate an evolutionary science of life driven by an alternate mechanism. In France his main ideas were preserved through the efforts of his colleague Etienne Geoffroy Saint-Hilaire (1772–1844), and elaborated a generation later by biologists such as Alfred Giard (1846–1908). The neo-Lamarckian school in the United States was led by paleontologist

Edward Cope (1840–1897) and other scientists who combined diligent fieldwork with a distinctive theistic metaphysic. Their journal *The American Naturalist* called for a new natural theology built upon perceived evidence of divine purpose in the environmental adaptation of organisms. In contrast, the French neo-Lamarckian school was secular in flavor, rejecting any intent of discovering divine purpose in nature, illustrating how neo-Lamarckism as a scientific theory was compatible with a wide variety of conflicting theological and metaphysical interpretations.

See also DARWIN, CHARLES; EVOLUTION; NEO-DARWINISM

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LANGUAGE

Human mental life includes biologically unprecedented ways of experiencing and understanding the world, from aesthetic experience to spiritual contemplation. Nevertheless, the origins of many of the most distinctive human mental attributes are likely intertwined with the origins of language. Language is without doubt the most distinctive human adaptation. There is almost no realm of human cognition unaffected by it. Yet there is still debate over even the most basic aspects of its nature, including the degree to which linguistic competence can be coaxed from other species (e.g., apes, dolphins, and parrots); what the neural basis for this distinctive capacity is; and when exactly in human ancestry this capacity emerged and matured to its modern level. There is little doubt that some substantial role is played by distinctive aspects of human biology. Both the special adaptations for language and language itself have played important roles in the origins of human moral and spiritual capacities.

The evolution of language ability in humans

The relative contributions of biological versus cultural aspects of language cognition depend on its evolutionary antiquity. If languages have a shallow prehistory (less than one hundred thousand years), we can expect little correlated biological restructuring of cognition as a result, except insofar as required to get this capacity off the ground. In this case, most of its influence will be traced through cultural processes. If languages have a deep prehistory (on the order of a million years), however, then we can expect that human cognitive and emotional systems have been substantially shaped by its ubiquitous presence in all aspects of human social life. This also should correlate with the extent to which human ethical and spiritual sentiments have become a part of human nature, as opposed to mere cultural overlays on ape nature.

Assessing the origins of these abilities is complicated by the fact that no direct consequences of language use are preserved in the fossil record. Paleolithic archeological evidence for symbolic expression that may signal well-developed linguistic and spiritual activities is well known from European cave paintings and carvings and Australian rock paintings, and from evidence of intentional burials (possibly including Neanderthal burials, as well as the burials of anatomically modern humans). Though the creation of icons and burial of the dead are not guarantees of shamanistic or religiouslike activities, they do suggest the existence of sophisticated symbolic reasoning, and this is a crucial correlation. The first sculpted and pictorial forms can be dated to no earlier than about sixty thousand years ago, and the most well known date to within thirty thousand years ago. This is quite recent, considering that hominids have been on a separate evolutionary track from other African apes for at least five million years, that members of species similar enough to be included in the genus *Homo* have been around for 1.8 million years, and that the human species *Homo sapiens* is at least two hundred thousand years old. In general, these earliest samples of expressive symbolism must be understood not as evidence for the initial evolution of symbolic abilities but rather for their first expression in durable media. They likely had long been incorporated into conventionalized social activities by that time. The origins of the symbolic traditions that these works express in material form could easily anticipate this data by an order of magnitude.

To get some idea of the possible extremes of this range of possible dates consider the following. The earliest direct archeological evidence of language is, of course, in the form of early forms of writing, which are all less than ten thousand years old, and most considerably more recent (about five thousand years ago). Since not even the most radical theorists among archeologists and paleontologists would date the appearance of modern languages more recently than about fifty thousand years ago, this late externalization of language offers a curious challenge: Why did it take so long for this most important means of communication to exhibit direct external expression? The same question can be asked of the first evidence of pictorial and carved forms, which date back about sixty thousand years in Europe and Australia and possibly earlier in Africa (though this African evidence is currently less well known). Assuming some comparable difficulties in externalizing these different modes of symbolic expression, we might suggest that, most conservatively, the corresponding distinctively human symbolic communication must be at least ten times as old; that is, 5,000 to 50,000 years for modern language, and 50,000 to 500,000 years for some form of language.

At the other end of the spectrum, there is a series of apparently linked paleontological transitions evident between 1.6 and 2.4 million years ago in Africa that suggest that the beginnings of symbolic communications in some form may date to this fossil epoch. The first clear evidence for the regular production of stone choppers, at a site called Gona, can be dated to about 2.4 million years ago. These are associated with fossil species of the genus *Australopithecus* (possibly *A. garhi*). Australopithecines exhibited ape-sized brains, relatively large jaws with heavy dentition (evidence of a vegetarian dietary adaptation), relatively modern bipedal locomotion, and also a characteristic sexual dimorphism (males much larger on average than females), which is indicative of male competition over females in a polygynous mating system that is fairly typical of monkeys and great apes. By 1.8 million years ago a number of fossil sites begin to demonstrate hominid species with larger brains and reduced dentition, correlated with extensive stone tool assemblages. These features have prompted paleontologists to cite this as the point where our genus, *Homo,* begins. By 1.6 million years ago members of our genus, with brains beginning to cross into the low end of the modern range, had left Africa to spread into Asia, Southeast Asia, and possibly throughout more temperate Asian regions as well, taking with them more sophisticated tools. Given these unprecedented features, there can be little doubt that some significant changes in communication and cognition also are contemporaneous with these transitions—the first forms of crude symbolic communication—though it is likely that the evolution of modern forms of linguistic communication took much longer to develop.

If symbolic communication has been around in some form for as much as two million years then we can expect it to have had significant consequences not just for human culture but also for human brain function. The evolutionary biological effect of a behavioral adaptation such as this may be usefully compared to that of dam building in North American beavers. The evolution of this ability has changed the niche in which beavers mature and live, and this has changed the natural selection forces affecting beaver physiology and behavioral propensities in succeeding generations. Thus, beavers exhibit extensive aquatic adaptations as a feed-forward result of beaver behaviors. This evolutionary process has been called *niche construction.* The effects of human symbolic communication and culture can also be understood as a form of niche construction, though symbolic culture is in many ways a far more all-encompassing niche than a beaver pond. This niche likely favored the evolution of certain cognitive capacities and social predispositions relevant to symbolic learning and communication, but also, as in the case of beavers, there may be many special features of this artificial niche that are idiosyncratic to it. Thus, there is good reason to expect that human brains have been reorganized in response to language, a reorganization that included changes affecting emotional, social, and communicative tendencies, as well as mnemonic, attentional, and motor capacities supportive of symbolic communication. Anatomical hints of this effect are evident in the changes in regional brain proportions (e.g., disproportionately expanded prefrontal cortex), cortical vocal control (unprecedented among mammals), and lowered laryngeal position. Hints from behavior are even more extensive. These include the convergent contributions of many systems to this capacity, its robustness in the face of variations in learning conditions and the effects of early brain damage, its highly predictable developmental progression, the remarkable universality of many of the structural features of languages, and its unprecedented efficiency. These effects need to be understood also with respect to the complex cultural dynamic of language change, which itself is a kind of quasi-evolutionary process. The ways different languages carve up the meaning and reference "space" and the syntactic systems that organize linguistic expression clearly change and evolve over historical time, and probably with respect to these biological predispositions and abilities as background.

Consequences of language ability for religious and spiritual development

The consequences of this unprecedented evolutionary transition for human religious and spiritual development must be understood on many levels as well. There are reasons to believe that the way language refers to things—symbolic reference—provides the crucial catalyst that initiated the transition from species with no inkling of meaning in life to a species where questions of ultimate meaning have become core organizers of culture and consciousness. Symbolic reference is reference to things and ideas that is mediated by an intervening system of symbol-symbol relationships, as well as conventions of use that allow there to be considerable conceptual "distance" between a sign vehicle and its object of reference. Unlike *icons,* which refer by means of structural similarities between a sign vehicle and its object, or *indices,* which refer via their physical contiguity or invariant causal correlation with their object, this conceptual "distance" is an intermediate referential step that allows the form of symbols to be entirely independent of the objects to which they refer. Symbolic reference is thus both arbitrary and capable of providing considerable displacement and abstraction. *Displacement* refers to the capacity to refer to things distant in space or time, and *abstraction* refers to the ability to represent only the more spare and skeletal features of things, including their logical features, such as whether they are even ontologically existent. So it is with the evolution of this symbolic capacity that it first becomes possible to represent the possible future, the impossible past, the act that should or shouldn't take place, the experience that is unimaginable even though representable. These capacities are ubiquitous for humans and largely taken for granted when it comes to spiritual and ethical realms, but this is precisely where crucial differences in ability mark the boundary that distinguishes humans from other species.

Consider the ethical dimension of humanness. Though the family cat may gleefully torment a small animal causing its terrifying and painful death, few among us would consider this a moral issue concerning the cat, though whether to intervene may be a moral dilemma for us. Even when a large predator, say dog or bear, happens to maul and kill a human being, efforts to destroy the animal are not accompanied by moral outrage, just a desire to prevent further harm. But the situation is very different in cases where humans perform similar actions. It is not merely that we consider nonhuman predators to be guiltless because it is in their nature to kill. We hold them guiltless because we believe they lack a critical conception of the consequences of their actions on their victim's experience. This ability to anticipate and to some extent imagine the experience of another are critical ingredients in this moral judgment.

This does not mean that other creatures are merely selfish robots. Selfless behaviors of a sort are not at all uncommon in other species. Caregiving behaviors by parents are nearly ubiquitous in birds and mammals, and what we might call prosocial emotional responses and predispositions that cause individuals to behave in ways conducive to social solidarity are especially widespread among social mammals. However, there need be little or no role played by intersubjective considerations in the generation of these emotions and their associated care-giving, protective, and comforting behaviors. And if that is so, then it may not be appropriate to consider these as moral or ethical, even incipiently.

There is good reason to believe that the capacity to represent the intentions and experiences of others is deeply dependent on human symbolic capacity. This is because it is a difficult cognitive task. It involves generating something like a simulation of oneself in different circumstances (i.e., projected from another individual's point of view), and it must include the emotional experiences this would invoke as well. This representation is perhaps supported by recall of images from analogous past experiences, juxtaposed against the images and emotions of current experience. But the salience of direct experience, especially one's current emotional state, poses a difficult impediment to simultaneously representing the perspective of this other simulated emotional experience. Holding such mutually contradictory representations in mind at once is a difficult task, even when there is little emotion involved, but it becomes deeply challenging when the exclusive states are heavily emotion-laden.

All such cognitive tasks depend critically on the prefrontal lobes of the cerebral cortex. This brain region is essential to any mental process that requires holding the traces of alternative associations and behavioral options in mind to be compared, so that one can act with respect to likely consequences and not merely with respect to their general reinforcement value or their stimulus salience. Reduction of such stimulus drives allows the most effective sampling of options. It is suggested that the prefrontal lobes are disproportionately enlarged in human brains as an evolutionary adaptation to the demands imposed by symbol learning and use. The indirectness of symbolic reference demands a shift of attention away from immediately associated features and to the relational logic behind the symbols, which binds them into a system. So this neuro-anatomical divergence from the ancestral condition likely contributes to the capacity and perhaps even a predisposition to generate the "simulations" required for the representation of others' experiences.

But it is the referential displacement provided by symbols themselves that is probably critical to reducing the differential in salience of competing emotional state representations to make this mental comparison possible. Studies with primates and children have shown, for example, that failures to make optimal choices when highly arousing stimuli (e.g., candy) are presented can be overcome by substituting representations for the actual thing. By a somewhat ironic logic, then, it may be the capacity to use representations to reduce the emotional salience of particular experiences that has enabled the development of intersubjective empathic abilities.

Symbolic reference also provides a critical support for an additional element of ethical cognition: the need to project forward the consequences of different possible alternative actions. Projecting the plausible physical consequences with respect to one's own needs and desires is difficult enough, but simultaneously projecting the likely affect on another's experience is doubly complicated. This is the mental equivalent of running simulations of the effects of simulated actions on simulated emotions, all in conflict with current experiences and emotional states. As the numbers of potentially interfering images and the intensities of the potentially conflicting emotions increase, the importance of symbolic support grows. For this reason, not only do we recognize that young children have difficulty performing anything beyond simple moral assessments, but all cultures actively provide narrative and ritual exemplars for guiding its members in handling ethical matters. The symbolic traditions that constitute cultures almost universally transmit the expectation that one is responsible for considering experiential consequences for others before acting—a moral imperative. Of course, it is also this capacity for imagining the experiences of others that makes possible the most heinous of human acts, such as extortion and torture. The emergence of good and evil are not, then, just mythically linked. Both are implicit in the symbolic transfiguration of emotional experience and the gift of intersubjectivity that results.

Ultimately, humanness may be most clearly marked by this transformation of the merely physical and physiological into the meaningful and implicitly value-laden by virtue of symbolic reference. Under the influence of the generalizing power of symbols this experience of ethical significance can be extended well beyond the social sphere, to recognize an ethical dimension implicit in all things. This suggests a way to think about two additional features that are characteristic of most spiritual traditions: the ubiquitous assignment of symbolic meaning, purpose, and value to things outside human affairs (e.g., origins, places, natural phenomena, and life and death itself), and the presumption that there is something like intentionality or intelligence behind the way that things are and the unfolding of worldly events.

Both of these nearly universal tendencies reflect a complex interaction between the cognitive predispositions that have evolved to ease the acquisition of symbolic communication and the implicit power of symbols to alter conditions of life in the world. Since a prerequisite to symbolic reference is the "discovery" of the logic of the system of inter-symbolic relationships that supports any individual symbolic reference, there are reasons to believe that the changes in prefrontal proportions contributed not just an ability to sample these non-overt relational features, but also a predisposition to look for them. With symbols, what matters is not surface details, but a hidden logic derived from the complex topologies of semantic relationships that constrain symbol use.

So the neuropsychological propensity to incessantly, spontaneously, and rapidly interpret symbols should express itself quite generally as a predisposition to look beyond surface correlations among things to find some formal systematicity, and thus meaning, behind them, even things that derive from entirely nonhuman sources. Everything is thus a potential symbol—trees, mountains, star patterns, coincidental events—and if the systematicity and intentionality is not evident it may mean merely that one has not yet discovered it. Symbolic meaning is a function of consciousness and symbols are produced to communicate. So if the world is seen as full of potential symbols, it must implicitly be part of some grand effort of communication, and the product of mind. Whether this projected subjectivity is experienced as different personalities resident in hills, groves of trees, or rivers, or as some single grand infinite mind, this personification also taps into the intersubjective drive that is also fostered by symbolic projection.

In summary, the role of symbolic communication, and especially language, in moral cognition is ubiquitous. It has played a role in the evolution of a brain more capable of the cognitive operations required; it has provided critical tools for easing the implicit cognitive strain of performing these mental operations; and it has made it possible for societies to evolve means for developing these abilities (as well as opening the door for the horrors of their abuse). Moreover, the capacity for spiritual experience itself can be understood as an emergent consequence of the symbolic transfiguration of cognition and emotions. Human predispositions seem inevitably to project this ethical perspective onto the whole world, embedding human consciousness in vast webs of meaning, value, and intersubjective possibilities.

See also SEMIOTICS

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LAWS OF NATURE

It is generally held that the search for laws is part and parcel of natural science. Statements of the laws of nature provide the most systematic and unified account of phenomena; they are used to make predictions, and they figure centrally in explanation. But are the laws of nature real? Do they belong to the world or do they rather reflect the way people speak about it? Do they merely describe the facts and processes in nature or do they govern them? In other words, do laws possess a modal force, the force of nomological necessity, not attaching to merely contingent facts? And if they do, how does one get a handle on this important distinction between laws and nonlawful accidental generalizations? These questions continue to be widely debated and there is no generally accepted philosophical theory of the laws of nature. It is also unclear whether any single theory could do justice to the diverse kinds of laws used in different scientific disciplines (physics, chemistry, biology, psychology, etc.). Finally, it is a matter of controversy how the laws of various disciplines are related to each other.

Do laws describe or prescribe? Some historical background

The question of whether laws describe or prescribe the course of nature has always been given particular emphasis in the debates. Most historians agree that the concept of scientific law as it is used today did not become widely accepted until the scientific revolution marking the birth of modern science. The ancestors of this concept, however, are old and include the ideas of social, legal, and moral order, which themselves can be traced to the notion of divine legislation. This notion is clearly associated with the prescribing force various laws (*lex, regula*) possess due to their origin in God's will—be they the natural laws of moral conduct or the laws of mechanics. The mathematician and philosopher René Descartes (1596–1650), in particular, explicitly related his law of inertia to the sustaining power of God. Even as late as the Enlightenment age, philosophers such as Montesquieu (1689–1755) attributed the order of nature to the hand of God. But alongside this divine-necessitation understanding, natural scientists and philosophers as different as Roger Bacon (c. 1220–1292) and Johannes Kepler (1571–1630) advanced a quite different conception of law that was free of theological connotations and had to do with observable and measurable regularities in nature. The view of laws as regularities capable of being inductively inferred (or even "deduced," as Isaac Newton [1642–1727] thought) from phenomena and then used in prediction and explanation became firmly entrenched in the new science of mechanics and in many other disciplines in the decades following the scientific revolution. Such regularities were widely interpreted as being descriptive, not prescriptive. Rather than being imposed on phenomena, they simply reflected the way things are. This interpretation received a stamp of approval in the empiricist tradition and especially in the philosophy of David Hume (1711–1776). In was, however, challenged in twentieth-century philosophy, especially after the demise of logical positivism, the rise of scientific realism, and the revival of metaphysics.

A taxonomy of scientific laws

The sciences display a wide variety of laws. Some laws are deterministic, the paradigm example being the laws of Newtonian mechanics, which prompted the astronomer Pierre Simon Laplace (1749–1827) to invoke his famous image of a demon capable of performing an arbitrary number of calculations in a finite amount of time. If the demon knew all the laws pertaining to the interaction of matter particles and the exact configuration of all the matter in the universe at a certain moment of time, he would be able to predict with absolute accuracy the state of the entire world at any future moment, as well as retrodict its past states. Given the deterministic laws and initial conditions, there is only one way for the phenomena and processes to occur. Probabilistic or statistical laws, in contrast, only attribute a certain probability to such occurrences. The laws of statistical mechanics, of Mendelian genetics, and of social and economic development are in this category. Since such laws are not the most fundamental laws of reality, however, their probabilistic character may not be irreducible. But if the currently dominant interpretation of quantum mechanics is correct, then indeterminism is a feature of even the most basic laws of nature.

Laws pertaining to natural processes (deterministic or not) and relating their earlier and later stages (e.g., a putative chemical law to the effect that putting together substances *X* and *Y* results in an explosive reaction) are often referred to as causal laws. The relationship between causal laws and causation (in particular, whether the former are constitutive of the latter) is a matter of dispute. Far from all laws are causal, however. Some laws assert a synchronic dependence among several quantities (e.g., the ideal gas law relating pressure, volume, and temperature). Still other laws state that an entity of a certain kind has a certain property (e.g., water's boiling point is 100° C).

Finally, there are conservation laws (of matter, momentum, energy, etc.), other basic principles such as relativistic and gauge invariance, and prohibitions such as Pauli's exclusion principle and the principle ruling out superluminal signals. How should they be classified? Are they on the same footing with other laws? Or are they rather second-order constraints on first-order laws? In any case, they are of paramount importance. Thus the invariance of some physical quantities with respect to coordinate and other kinds of transformation is bound up with the concept of symmetry and has been a powerful heuristic tool in the search for the fundamental forces of nature.

This classification of various types of laws can be extended in many directions. The diversity of laws calls into question any attempt to provide their universal form.

Philosophical theories of laws

Philosophical theories of laws are focused on the ontological status of the latter. In many ways, the ongoing debate about this status is a successor of the older dispute between the descriptive and prescriptive views of laws. It is hard to get rid of the feeling that when water boils at 100° C (under normal atmospheric conditions), it does so not simply as a matter of fact but out of necessity. Moreover, if no samples of water were ever heated to 100° C, it would still be true that, were an arbitrary water sample so heated, it would boil. Advocates of necessitarian theories attribute this necessity to nature and hold some facts about the world responsible for the modal power inherent in natural laws. Philosophers in the empiricist tradition, however, have always thought otherwise. Instead of attributing nomological necessity to nature, they have attempted to achieve the effect of this necessity by working in rather barren metaphysical landscapes. In spite of the sustained critique leveled against this attitude beginning in the early 1960s, it remains very influential, under the name of the *regularity theory*.

According to this theory, laws of nature are nothing but universal truths of spatio-temporally unlimited scope that can, in many cases, be expressed by quantified material conditionals involving only qualitative and local predicates: $(\forall x)(\mathrm{P}x \supset \mathrm{Q}x)$; for example, "All frogs are green," "All metals expand when heated," "All electrons have a unit electric charge." Laws, in other words, are cosmic regularities. On this view, being such a regularity is necessary and sufficient for being a law. What makes it a matter of law that water boils at 100° C is the cosmic fact about the instantiation of first-order properties—the fact that all actual samples of water at 100° C found in the history of the universe have boiled, are boiling, and will boil. The manifestly Humean character of this concept of lawhood made it one of the cornerstones of logical positivism.

The regularity theory confronts many problems. First of all, being a cosmic regularity is neither necessary nor sufficient for being a law. Some laws are probabilistic (e.g., those of quantum mechanics) and hence compatible with any actual degree of correlation between the relevant *P*'s and *Q*'s. There are also uninstantiated laws. For example, Newton's first law, which states that an object will remain at rest or in uniform motion in a straight line unless acted upon by a net external force, probably has no instances at all. It is (arguably) a genuine law of nature nonetheless. Thus being a (cosmic) regularity is not necessary for being a law.

It is also not sufficient for it. To use the renowned example of the philosopher Karl Popper (1902–1994), suppose every moa (an extinct species of bird in New Zealand) that ever lived died before age fifty as a result of some ubiquitous disease, thus giving an instance of cosmic regularity. There is, however, no law corresponding to this regularity. Every moa could have lived longer but, as a matter of fact, has not. The regularity in question is merely accidental, not genuinely lawful. But the theory is incapable of distinguishing these two cases.

This has prompted a modification in the regularity account based on the notion of counterfactual conditional. Genuine laws of nature, but not accidental uniformities, can be said to support (that is, imply) the relevant counterfactuals. Thus the regularity from Popper's example does not imply "If something were a moa, it would have died before age fifty." On the other hand, a genuine law that moa have a certain number *n* of chromosomes does imply the counterfactual "If something had been a moa, it would have had *n* chromosomes." To be able to use this criterion, however, one needs an independent account of truth conditions for the relevant sort of counterfactuals, namely, those that are not also counterlegals violating the laws of nature. But it is hard to see how one could know which counterfactuals are true and which of them are not counterlegals without already knowing what laws of nature there are.

It has been argued that laws, but not mere regularities, possess considerable explanatory power. While this is true, it can hardly serve as a criterion of lawhood. Something is not made into a law when its statement becomes explanatorily powerful. It is powerful because it is already a statement of law. A similar objection applies to the best version of the regularity theory, which was anticipated by John Stuart Mill (1806–1873) and Frank Ramsey (1903–1930) and elaborated in the 1970s and 1980s by David Lewis (1941–2001). According to Lewis, "a contingent generalization is a law of nature if and only if it appears as a theorem (or axiom) in each of the true deductive systems that achieves the best combination of simplicity and strength" (p. 73). This account makes lawhood relative to merely epistemic (hence subjective) standards of simplicity and strength pulling in opposite directions.

These and other problems have led to the emergence of necessitarian alternatives to the regularity theory. One such alternative, widely known as the Dretske-Tooley-Armstrong theory, takes laws to be grounded in relations between universals. A lawful regularity, such as the fact that all metals are electric conductors, obtains because *being a metal* nomologically necessitates *being an electric conductor.* Although such a relation between the two universals, *metallicity* and *conductivity,* is itself contingent (could have failed to take place), its actual presence confers on particular facts falling under it the right sort of necessity (i.e., the nomological of physical necessity), which sustains the relevant countarfactuals and accounts for the explanatory power of this law. On the contrary, no relation of necessitation obtains between *being moa* and *dying before age fifty.* The corresponding cosmic regularity is still there but only as a matter of historical accident, not as a matter of nomological necessity.

To uphold such a theory, however, one has to accept, not only real universals (entities such as *metallicity,* in addition to actual metals) but also contingent relations of nomic necessitation between them. Such relations must then translate into the relations among particulars. Some authors have argued that these commitments create serious difficulties (Bas van Fraassen's problems of identification and of inference).

The second major type of necessitarian theory states that laws derive from causal powers (dispositions and propensities) of objects. The possession of such powers by natural kinds of objects (e.g., elementary particles, chemical elements) disposes their bearers to behave in specific ways or to exemplify other characteristic properties. On this account, most properties—and especially those of the fundamental objects—are ultimately dispositional in nature. For example, the electric charge possessed by the electron disposes the latter to interact in a certain way with the electromagnetic field. Laws of nature, on this account, simply codify the natural behavior of things enforced by their intrinsic causal powers. Moreover, natural kinds possess their dispositional properties essentially: Nothing counts as an electron unless it has a unit electric charge, a specific mass, spin 1/2, and perhaps other essential dispositional properties. The major difference of this account from the relations-between-universals view is erasing the boundary between what things are and how they behave. On the former view, all electrons have a certain charge because of the relation between the two universals: *electronhood* and a determinate *chargehood.* On the latter view, part of what makes something an electron is having a certain charge. Instead of being imposed "from above," in the form of the necessitation relation between universals, lawhood emerges "from below," from the ascription of essential dispositional properties to particulars.

One difficulty with this view is that it raises the specter of *virtus dormitiva*: Causal powers of fundamental objects turn out to be their irreducible dispositional properties that must be possessed even when they are not manifested. But what exactly is involved in saying that a certain substance has an irreducible disposition that is not currently manifested? What keeps such a pure disposition in existence? Other questions arise: Do fundamental objects, such as electrons, have one disposition or many? If many, what accounts for their connection?

Thus all major philosophical accounts of laws have their difficulties. This has led some authors to skepticism about the possibility of a satisfactory analysis of lawhood or even to the view that the notion of law must be rejected altogether as being empty, obsolete, and having no important role to play in contemporary science. This, however, remains a minority view. Most philosophers (and probably all scientists) continue to think that laws are important, even if their ontological nature is elusive.

Laws and explanation

Even if explanatory potential does not by itself make something into a law, the ubiquitous role of laws in scientific explanations is beyond doubt. This observation has formed the basis of the covering-law model of explanation introduced in 1948 by the philosophers Carl Hempel (1905–1997) and Paul Oppenheim (1885–1977) and further elaborated by Hempel in the 1950s and 1960s. To explain a particular phenomenon is to answer a why-question, and this requires an account of how the phenomenon was brought about. Hempel has construed deterministic explanation as a deductive argument of the form:

$$\frac{\begin{array}{l} C_1, C_2, \ldots, C_n \\ L_1, L_2, \ldots, L_m \end{array}}{E}$$

Here $C_1, C_2, \ldots, C_n$ are statements describing the initial conditions and $L_1, L_2, \ldots, L_m$ are statements of laws (together constituting the *explanans*), while E is a statement describing the event to be explained (the *explanandum*). Thus to explain why a particular sample of metal expanded when heated, one invokes a law to the effect that all metals do so when heated and the initial condition stating that the sample in question was heated. The above deductive-nomological schema has a probabilistic (statistical) counterpart to account for explanations involving indeterministic laws.

Since its inception the covering-law model has been the target of many objections. But it is still the starting point of any informed discussion of explanation. It is plausible that most deficiencies of Hempel's model are ultimately due to its implicit reliance on a broadly Humean (i.e., regularity) conception of laws.

Laws and reductionism

Whether higher-level laws of nature (chemical, biological, psychological, etc.) are reducible to the fundamental physical laws—and if so, in what exact sense—is part of the problem of reductionism. However natural it may seem to think that chemistry is eventually just a chapter of physics, many authors have resisted this line of thought. Even physicists have always doubted that the irreversibility inherent in the second law of thermodynamics can be explained on the basis of time-reversal invariant laws of mechanics. Developments in chaos theory have all but deepened such doubts.

See also CAUSATION; DETERMINISM; SYMMETRY

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LEVEL THEORY

Level theories are used to explain the relationship between different academic disciplines and the realities that they describe. Drawing on concepts of emergence and supervenience, level theories seek to counter the claim that all of reality can be explained as nothing but a collection of atoms. Various scholars in science and religion have argued that reality should be understood in terms of increasing levels of complexity, each level emergent from, but not reducible to, the levels below.

See also COMPLEXITY; EMERGENCE; HIERARCHY

GREGORY R. PETERSON

LIBERATION

Liberation is a central religious notion both in South Asian religious traditions and in contemporary Christian theology, but in what way are South Asian meanings of liberation (*mokṣa, mukti, nirvāṇa*) comparable to liberation as understood by contemporary Christian theologians? This entry will highlight significant differences regarding the meanings of liberation across traditions, then draw conclusions about the meaning of those differences for how each tradition engages the sciences. The discussion will focus on those traditions that seem most philosophically unlike Western religious traditions, namely the nondualism of Advaita Vedānta (constituted as a school by the eighth-century theologian, Śaṇkara) and Buddhism, particularly the Madhyamaka tradition (inaugurated by first-century C.E. Buddhist philosopher Nāgārjuna).

Success in cross-cultural comparison requires examining what South Asian religious traditions seek to be liberated from. There is greater agreement about the nature of the predicament that makes liberation necessary than about how to escape. The reason for this wide divergence is plain: Each South Asian tradition (indeed each subtradition) has a unique understanding about the nature of the ultimate reality to which liberation leads. Nevertheless, nearly all concur in their assessment that all beings are beginninglessly bound to *saṃsāra,* the wheel of rebirth or transmigration, by the force of karma. The question about just what causes karmic bondage quickly reintroduces serious debate both within and across South Asian religious traditions.

South Asian traditions, although they have typically maintained that all sentient beings are in bondage, have traditionally been anthropocentric in focus. Even if all beings are in bondage, it is primarily human beings who can be liberated. Moreover, only individual human beings, not communities, are liberated from the cycle of transmigration. Human bondage is rarely construed in sociopolitical terms. Liberation is understood largely as a matter of freedom from afflictions of the heart and ignorance of the mind, the root causes of bondage to the process of rebirth. Liberation from craving, ignorance, and delusion (the three poisons in Buddhism and also in Śaṇkara's Advaita) does lead to more compassionate living, but the essential locus of transformation is the person.

Until contemporary attention to ecological matters transformed Western religious thinking, Western traditions have also been anthropocentric in character. And, like South Asian traditions, the religious goal has most often been understood as salvation for individual human beings. Salvation was understood as healing, as a reunion with God that brings about the reintegration of the divided self and reconciliation with neighbor. A comparison that focused on salvation as healing would find important similarities with the South Asian goal to be free from craving, ignorance, and delusion.

However, for nearly the entire history of Western monotheism, the predicament from which one needs to escape has always included a sociopolitical component, even when that component has been muted by the quest for personal salvation. The sociopolitical character of Western religious anthropologies has meant that communities qua communities, and not just individual persons, can and must be healed. Communal healing requires doing justice. Doing justice in turn has concretely meant the liberation of persons from oppressive socioeconomic and political structures that disfigure human flourishing. This is the meaning of liberation that finds vital expression in contemporary Christian liberation theology.

Here, communities are liberated and their collective well-being is the focus. Liberation is not construed as individual escape from the threat of an otherworldly judgment but freedom from a this-worldly hell. This particular kind of communal liberation is not commonly found in South Asian religious reflection. The compassionate presence of liberated individuals can and does have social and political consequences, but groups and communities are not liberated in their collectivity. This deep difference has important ramifications for thinking about the scientific implications of the notion of liberation in Western and South Asian thought.

The human predicament in South Asian religions

The human predicament in South Asian religions is construed as bondage to a beginningless process of rebirth. That process is fueled by karma, which generates consequences for all human actions, consequences that exert their presence across multiple lifetimes. That law-like process is driven by some fundamental affective cause, usually described as craving. Craving leads persons to act, and action in turn generates the consequences that insure rebirth.

But craving itself is analyzed as deriving from a cognitive factor, namely ignorance. What exactly one is ignorant of depends on the specific tradition in question. Ignorance is always the failure to know or realize what each tradition takes to be ultimately true. For example, whereas Advaita Vedāntins argue that persons are ignorant of their true, infinite, and unchanging Self (*ātman*), South Asian Buddhist schools concur in arguing that ignorance consists in entertaining the very idea of any substantial, enduring or permanent self (*anātman*).

This analysis of the root causes of transmigration indicates yet another meaning of liberation in South Asian traditions. Liberation is not understood merely as a post-mortem escape from the cycle of rebirth. Liberation is also the cessation of ignorance and the elimination of the three poisons in and through which ignorance is expressed and perpetuated.

Action, karma, craving, and ignorance are all crucial links in a complex chain of causes and conditions that extend over multiple lifetimes by which the process of transmigration operates. The Buddhist term for this complex cycle of causes and conditions (*hetupratyaya*) is *pratitya-samutpāda,* best translated as "dependent co-origination." Buddhist and Hindu reflection on liberation focuses precisely on those cognitive, affective, volitional tendencies that generate karma because the cycles can be interrupted precisely at these points. But the vision of complex causality and interdependence evinced in the chain of links that both perpetuates and is the process and reality of transmigration is worthy of attention to those interested in the implications of Hindu and especially Buddhist thinking about science.

Despite radical disagreements about the object of ignorance, these traditions do agree that "ignorance" does not refer to matters of everyday experience. There are all sorts of things that an enlightened person may not know about the empirical world which do not imperil liberation. Because liberating knowledge is knowledge about ultimate matters and not conventional ones, religious knowledge is not contingent on, nor does it need to control, what counts as knowledge in conventional matters. Cosmology or quantum mechanics, theories about how the world works, either at the macroscopic or the subatomic realm, are not directly relevant to liberating knowledge. There is, therefore, the possibility of a comprehensively hands-off attitude about scientific ventures. The working and operation of the world are matters of conventional truth (*vyavahāra satya*).

The term "ignorance" refers to the failure to apprehend the ultimate truth (*paramārtha satya*) about the underlying nature of reality, about the being of things and not about how things work. A radical distinction is made between the operation of the world as it is ordinarily experienced and the ultimate truth about the being of things, even if, as it turns out later, these two perspectives turn out to be profoundly interrelated, as is the case in the Madhyamaka Buddhism of Nāgārjuna.

Ultimate truth and scientific truth: South Asian approaches

The possibility of radically severing religious truth from conventional truths that are the objects of scientific inquiry is far easier for Hindu nondualists than Buddhist nondualists. For the classical Hindu Advaitins like Śaṇkara, the empirical world, the experienced world, is not ultimately real. Nothing given in experience endures. It is intrinsically impermanent and doomed to perish.

The fleeting realities of everyday experience need a basis, a substratum, apart from which they would not be. That basis or substratum itself is free from change, beyond temporality, indivisible, self-identical, and intrinsically real. Because it is free from fragility, it is radically transcendent, but because it is the being of all things, it is also radically immanent as the ground and basis of the conventional world of experience. This reality is pure being (*sat*) and is known as *brahman*. Only this underlying reality is truly real and thus this tradition qualifies as nondualistic. From the point of view of persons, liberation consists in coming to know that one is in truth this ultimate reality and not the finite self of ordinary experience.

The Buddhist nondualism of Nāgārjuna is strikingly different from Advaita Vedanta. Nāgārjuna's nondualism is a radical reinterpretation of early Buddhist insights regarding the impermanent dependent co-arising of things. Nāgārjuna argues that the pluralistic view of reality in which each thing is a stream or a flow of momentary arisings does not represent the deepest truth taught by the Buddha. The ultimate truth taught by the Buddha is to be found in the affirmation that everything arises in dependence on the causes and conditions that give it rise. If everything arises through the causes and conditions that give it rise, then no thing has any intrinsic being or self-existence (*svabhāva*). Indeed, if anything did possess intrinsic being that did not arise dependently on causes and conditions, it would be unconditioned and therefore eternal. But no such things are given in experience. Nothing, in that sense, exists. Thus, the fundamental notion at the heart of Nāgārjuna's system is emptiness (*śūnyatā*), the affirmation that all is empty of self-existence.

Buddhist nondualism of Nāgārjuna's variety is different from the Hindu nondualism of Śaṇkara. Nāgārjuna's nondualism does not affirm a single nondual reality that lies beneath the unreal world of experience. Rather, Nāgārjuna's nondualism argues that conventional reality is nondual because it is fundamentally interrelated or relational. The reifying conceptual processes that lead one to believe that reality is thing-like, composed of a plurality of unrelated entities, is produced by craving and ignorance. Liberation here means removing those affective and cognitive afflictions that obscure persons from understanding the interrelatedness of all reality.

The implications of these two different kinds of nondualism for the relationship between science and religion are intriguing. Nondualist Hindus are freer to say that religion and science are unrelated and independent ventures because religious persons seek to know the infinite reality of *brahman* that undergirds all things but is itself beyond all particulars. Scientists are free to pursue their own investigations as are the religious because both attend to different dimensions of reality. Science explores conventionality but religion inquires about the ultimate truth of *brahman*. In the terms used by the philosopher Harold H. Oliver (1984), it is possible to read Advaitins as subscribing to a "compartment theory" of the relationship between religious and scientific truth because each has for its object a different "domain."

Unlike Advaitins, Buddhist nondualists of Nāgārjuna's variety cannot say that science and religion are inquiring about different domains. For Madhyamaka, there is no ultimate reality that lies beneath the conventional realm. Ultimate truth is simply seeing that everything conventional is empty of own-being. Emptiness is not an ultimate reality behind the world of phenomena. Thus science and religion must be two "complementary" ways of interrogating the same domain of conventional experience.

Buddhist nondualists, therefore, can more strongly expect that scientific knowledge should disclose that the world of experience is fundamentally relational. Just how and where this relationality will show itself is not the concern of Buddhist thinkers, although Buddhists do point to the strong parallels between Madhyamaka Buddhism and quantum mechanics. At a still deeper level, Buddhist thinkers can be suspicious of scientific models that imagine reality to be particulate, composite, and unrelated. Such models cannot falsify Buddhist intuitions because Buddhists maintain that spiritual transformation is required before persons are capable of experiencing reality as radically relational. Scientists are not themselves committed to these technologies of transformation but rather to technologies of experimentation. Consequently, Buddhists can have robust expectations about what the sciences are likely to discover and can celebrate those discoveries that seem consonant with Buddhist intuitions, but they need not predict or control scientific research.

Ultimate truth and scientific truth: comparative judgments

Christian liberation theologians and others committed to particular conceptions of the just social order called for by God may be constrained to be more intrusive in their stance towards the sciences, especially the social sciences. Such intrusion need not be supernaturalistic or irrational in character. For liberation theologians, scientific theories that mandate the inevitability of economic disparity are morally and theologically suspect, as are visions of the social order that suggest that coercion and hierarchy are unavoidable. Because such visions imply that a just, equitable, and free social ordering is impossible, they render liberation impossible, thus contradicting what the God of justice requires. Such *prima facie* contradictions can lead theologians to maintain that the science in question is pseudo-science or that unwarranted conclusions have been drawn from data capable of being otherwise interpreted.

The natural sciences are also suspect insofar as they suggest that human beings do not have the freedom or capacity to structure personal and social life in just and compassionate ways. Thus, if evolutionary biology or behavioral psychology is employed to undercut theological commitments to visions of full human flourishing, such scientific claims are subject to critical scrutiny and suspicion. It is safe to assume that Christian theologians of liberation are in general more likely than Buddhists to question the putatively authoritative discoveries of natural or social science. This possibility suggests that such theologians allow for what Oliver would call a "conflict theory" model of the relationship between religion and science, rather than a compartment or complementarity model, because both modes of inquiry are making incompatible claims about the same domain of experience in the same respect.

These differing approaches to liberation seem to be intimately tied to each tradition's understanding of ultimate reality. Hindus can, in principle, maintain that the quest for liberation can be radically independent and non-intrusive about matters scientific. Christian claims about liberation, on the other hand, are not about a transcendent reality that is unrelated to conventional reality (as *brahman* is). The possibility of conflict between what is theologically required and what the sciences indicate cannot be overlooked.

For Buddhist thinkers, liberation is understood primarily as the transforming insight that enables one to recognize the radically relational character of reality, a recognition that generates compassion. While the emphasis on compassion is shared across traditions, Christian understandings of liberation are intimately connected to reordering contingent economic and sociopolitical structures so that communities can be freed from oppressive ideologies and structures. A wholly irenic relationship with the natural and social sciences seems unlikely when liberation is so understood. It would appear that Madhyamaka (the Middle School) Buddhists truly do hold the middle ground between Advaitins and Christian liberationists. Although M?dhyamika Buddhists can expect and commend discoveries that confirm their own relational intuitions, they are not compelled to critique the results of particular scientific ventures.

See also BUDDHISM; HINDUISM; KARMA; LIBERATION THEOLOGY; TRANSMIGRATION

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LIBERATION THEOLOGY

Liberation theology originated in Latin America during the 1960s in response to poverty, oppression, and failed development strategies. Methodologically it is described as theology "from below," beginning with social-historical reality and analysis and reflecting critically on it in the light of Christian tradition. Through a process of *conscientisation,* oppressed peoples are themselves involved in doing theology. The Exodus theme and the biblical motif of God's option for the poor are used as paradigms for reflection. Other theologies subsequently developed using the same methodology. These include black theology and feminist theology, which respond respectively to racism and sexism. All forms of liberation theology make use of social, economic, or political analysis in order to construct a stable interpretation of the conditions of life from which liberation is sought.

See also ECONOMICS; LIBERATION

JOHN W. DE GRUCHY

LIFE AFTER DEATH

Myths that explain the origin of death have been found among many cultures. Clearly, reflection on death and on life after death belongs to the oldest layers of religion. Yet because of the oral nature of these myths, their approach to the problem of death is relatively unsophisticated. A steady progress became possible only after the Greek invention of simplified writing. This process has continued through the twentieth century, and philosophy and theology, directly or indirectly, have exerted the most important influences on religious thinking about life after death.

The terms *soul* and *otherworld* have not always carried the same meanings during the course of history. "Primitive" conceptions of the soul were usually of two types: the so-called *free-soul,* which represents the individual personality but which becomes inactive when the body is active, and thus represents the person after death; and the *body-soul,* which endows the body with life and consciousness, and which perishes with the body. This dualistic conception of the soul changes when small "primitive" peoples become more differentiated. In these cases, the free-soul starts to acquire the qualities of the body-soul. The process is well documented in ancient Greece, where, after Homer, the free-soul (*psyche*), started to incorporate the *thymos,* the most important of these body-souls. As for the underworld, modern people are so used to thinking in terms of heaven and hell that they must be careful not to retroject them into earlier civilizations. Like ideas about the soul, conceptions of life after death have a history too.

Ancient Israel and ancient Greece

Even a cursory look at the Old Testament reveals that it has little to say about either soul or afterlife. In fact, ancient Hebrew does not even have a term equivalent to the modern English word *soul.* The closest equivalent is *nephesh,* which can be translated "life" or "life-force," but which can also signify the seat of emotions. Yet this term never refers to the "soul" of the dead, nor is it ever contrasted with the body. Israelite anthropology was strictly unitarian and remained so until influenced by the Greeks after Alexander the Great (356–323 B.C.E.). The grave must have played an important role in ancient Hebrew culture, since "to go down into the grave" (Gen. 37:35) is equivalent to "to go down into Sheol" (King James, Ps. 16:10). Sheol was a place located beneath the Earth, filled with worms and impossible to escape from, where the shadow-like deceased were supposed to continue their earthly existence. However, the scarcity of references to Sheol suggests that ideas about life after death were vague and played little role in the imagination of the early Israelites.

Ancient Greece presents a different situation. In Homer (c. 800 B.C.E.), who constitutes the earlist Greek source, the soul (*psyche*) does not yet have any connection with the emotions of living people. Yet in contrast with ancient Israel, the Greek notion of soul does represent people after their deaths. The soul goes straight to the underworld, Hades, an area located under the Earth, but also in the west; the soul can reach this "mirthless place" only by crossing the river Styx. The Greek picture of the underworld is bleak and sombre, causing the dead Achilles to remark: "do not try to make light of death to me; I would sooner be bound to the soil in the hire of another man, a man without lot and without much to live on, than be ruler over all the perished dead" (*Iliad* 11.489–491).

This traditional picture became radically nuanced in southern Italy during the fifth century B.C.E by Pythagoras (c. 570–495 B.C.E.) and the Orphics. The former is seen by many as the inventor of Western notions of reincarnation and celestial immortality. Unfortunately, information about the origin of ideas about reincarnation is scarce. It may well be that Pythagoras developed the idea in order to give his aristocratic followers new status in a time when the aristocracy was under stress. In any case, his new vision presupposed the idea of the immortality of the soul, an idea popularized by Plato (428–347 B.C.E.). Belief in celestial immortality became more evident around 432 B.C.E., when an official war monument pronounced the souls of fallen Athenians to have been received by the *aithêr* (upper air), but their bodies by the Earth. Shortly after Pythagoras, the Orphics, an intellectual movement named after the mythical poet Orpheus, introduced ideas about an attractive afterlife in the shape of a "symposium of the pure," where sinners had to wallow in the mud in a kind of hell. The contours of the Christian distinction between heaven and hell, then, first became visible in the fifth century B.C.E. This did not mean that the older ideas disappeared. On the contrary, belief in a life after death remained limited to a small group of intellectuals; most ordinary Greeks did not seem to have expected much of an afterlife. "After death every man is earth and shadow: nothing goes to nothing," states a character in Euripides' play *Meleagros,* and it is this attitude that predominantly survived into the Roman and Byzantine periods, even among Christians.

A startling new conception of the afterlife developed after Alexander the Great spread Greek civilization into the Mediterranean world in the last decades of the fourth century B.C.E. Before this time, the Greeks had denied the possibility of resurrection, but the publication of the Aramaic fragments of Enoch in 1976 show that among an as yet unidentified group of Jews the belief in resurrection, which is absent in the Old Testament, had become apparent already in the early second century B.C.E., although it was not until the Maccabean revolt that it became widely popular. Moreover, the same book of Enoch mentions heaven and hell. It seems likely that intellectual Jews had made contact with Greeks, probably in Alexandria, and had received information about Orphic views of the afterlife.

Although several groups of Jewish intellectuals, such as the Sadducees, the Essenes, and the community of Qumran (that has given us the Dead Sea Scrolls) continued to reject resurrection, others like the Pharisees enthusiastically took up the idea. However, the resurrection was not exported outside the Jewish world until the appearance of Jesus of Nazareth, although Jesus himself did not believe in the restoration of the former body, since the resurrected would be "like angels" (Matt. 22:23–33). The caution of Jesus was soon abandoned by his followers. In fact, Christian apologists and theologians spent an enormous amount of energy explaining and defending the resurrection, beginning with Paul's words: "For if the dead rise not, then is Christ not raised. And if Christ be not raised, your faith is vain" (1 Cor. 15:16–17). Indeed, all four gospels reach their dramatic climax with reports of Jesus' resurrection. Paul seems also to have been the first to present Jesus' resurrection as the beginning of the collective eschatological resurrection, whereas in traditional Jewish thought individual resurrection, as in the case of Jesus, had been typical only of martyrs, such as the Maccabees. This intellectual Christian effort becomes more understandable against the backdrop of Greek skepticism regarding the afterlife, a skepticism that was shared by the Romans, who had virtually no idea of an afterlife and, correspondingly, lacked an idea of an immortal soul.

The early Christian era and the Middle Ages

Early Christian ideas regarding life after death received great stimulus through the Roman persecutions. Whereas the New Testament had been reticent about the actual nature of the afterlife, it now became necessary to develop a picture that would help martyrs persist in their faith. Reports of executions of Christians during this time show the gradual appearance of new views of the afterlife, not surprisingly beginning in North Africa where funerary attention was more prominent than elsewhere in the Roman empire. Inspired by the Jewish idea of paradise as the place for the deceased, as well as by the great parks of contemporary local grandees, there arises an idea of heaven as an attractive landscape with a mild climate and plenty of light, where the deceased walk around in the body. Their main activity consists in praising God. This theocentric view of heaven would dominate until the Enlightenment. Hell, on the other hand, is little mentioned in the Christian literature of the first centuries C.E. Early Christian theologians were primarily interested in salvation, not damnation.

At the same time, the Jewish heritage of Christianity meant that a marked body-soul opposition was introduced relatively late in the second century by Christian intellectuals, such as Justin (c. 100–165) and Tatian (late second century), who were heavily influenced by Greek philosophy. They tapped Greek concepts of the immortal soul in order to bolster their arguments for the resurrection, albeit with a number of modifications, such as different fates for sinners and saved. Speculation about the soul, fed by Stoic and Aristotelian views, occasionally appears in the writings of later Church fathers like Origen (c. 185–254) or Augustine of Hippo (354–430), but they did not much influence ideas about life after death.

It is only in the early Middle Ages that a major change in attitude towards the afterlife appears. Christianity's growth from a minority into a majority, coupled with Augustine's stress on sin, led to an emphasis on hell rather than heaven in medieval views of life after death. Whereas Origen had argued for the temporary nature of hell, theologians like Augustine and Gregory the Great (c. 540–604) started to paint the penalties of hell in the most shrill of colors. The latter was more concrete than the former and thought that the penalties of hell started immediately after death, unlike Augustine and the early Church Fathers, who most often let them begin after the Last Judgment.

In the twelfth century, ideas about life after death became more differentiated. The Church introduced Purgatory as a third place for the dead, where they could be purified from their sins before they go to heaven. Strangely enough, the intellectual milieu where Purgatory was invented is still uncertain, but there are indications of a Cistercian origin, fueled by the need to counter the eschatology of the Cathars who had made salvation much easier than normative Christianity. Although the tripartite division of life after death was never accepted by Greek-Orthodox Christianity, it was promoted by scholastic theologians like Thomas Aquinas (c. 1225–1274). They did not agreed on all details, and disagreed in particular on the moment when the elect would attain full beatitude and the precise relationship between body and soul. Nonetheless, this general picture of the afterlife did not change significantly until the Reformation.

The Reformation and the Enlightenment

With the arrival of Martin Luther (1483–1546) and John Calvin (1509–1564) on the theological scene in the sixteenth century, God returned to center stage. The Reformation rejected Purgatory and, like post-Tridentine Catholic theologians, concentrated on the encounter with God in the hereafter. Until the eighteenth century, Western Christianity was united in seeing heaven as the place for the elect, where life was perfected by existing with God, without decay, but also without everything that characterizes human life, such as sex, illness, and family. The idea of hell, on the other hand, was increasingly questioned, especially after the reprinting of Origen's works during the Renaissance and after a rise in sensitivity towards the suffering of others.

During the Enlightenment, both Christians and adherents of natural religion could still agree on the idea of the immortal soul, but for the first time in Western history materialists and atheists could publicly, if guardedly, pronounce their views. They went too far for the majority, but in varying ways philosophers like Thomas Hobbes (1588–1679), John Locke (1637–1704), Denis Diderot (1713–1787), and Voltaire (1694–1778) now openly brought belief in eternal punishment into discredit. David Hume (1711–1776) could even claim, not without exaggeration, that the damnation of one man was an infinitely greater evil than the subversion of millions of kingdoms. It seems safe to say that ever since this time the traditional picture of hell has remained unacceptable to enlightened classes.

The picture of a static, theocentric heaven could also no longer satisfy an age more interested in man than God. Starting with Gottfried Wilhelm Leibnitz (1646–1716), but especially in the work of Emanuel Swedenborg (1688–1772), ideas about life in heaven became adapted to the anthropocentric needs of the time. Swedenborg promoted a view of heaven that was not so different from life on Earth. According to Swedenborg, the souls of the deceased entered a spirit world where human frailties were clearly visible. Only after perfecting their spiritual outlook could souls move on to heaven, where they became angels. Here, life on Earth was continued but in a more attractive setting of parks and palaces. Eating, drinking, and sexuality remained vital needs, friends and family could be met, and progress meant that men and women became more and more like "noble savages." Condemnations to eternal torment or a Last Judgement had no place in this vision. Such a stress on heaven in the era of the Enlightenment may be surprising, but in fact in Germany in the 1750s alone more than fifty treatises appeared discussing the problem of immortality. Evidently, growing scepticism led to deepened interest in defending immortality.

The nineteenth and twentieth centuries

Swedenborg's view coincided, and was probably part of, the Romantic interest in love between man and wife, and this interest was shared by Protestants and Catholics alike. Although Swedenborg was viciously attacked, even by Immanual Kant (1724–1804), he was triumphant, especially in America. The Transcendentalists became much enamored of Swedenborg's thought, and their influence was felt in America and Europe. The Unitarians in England, in particular, embraced the new insights against the more traditional views of the established churches. They began stressing that heaven consisted in "enjoying God through accordance with his attributes, multiplying its bounds and sympathies with excellent beings, putting forth noble powers and ministering, in union with the enlightened and holy, to the happiness and virtue of the universe" (Channing, pp. 225–226). Moreover, after Charles Darwin (1809–1882), this enjoyment was seen as the end of a long evolution. Immortality became a possibility rather than a reality. Similar conceptions of the afterlife were widely promoted in Germany as well. Naturally, even heaven could not escape the lure of Victorian "Muscular Christianity": "Want and pain, toil and trial, cannot be wholely banished out of *my* Heaven," wrote the brother of Cardinal Newman (Newman, p 34).

The heyday of Unitarian theology coexisted with the birth of spiritualism (1848). This movement would be the last attempt at proving scientifically the existence of the hereafter by means of controlled experiments. Yet the success of spiritualism would be short–lived; it was soon discredited by the frauds of its adherents and the trivialities of its results. Still, during its heyday, especially in America and England, its picture of heaven conformed closely to that developed by Swedenborg. Moreover, its rejection of hell, sin, and guilt was widely shared by liberal theologians everywhere.

By the end of the nineteenth century, the general picture of life after death had assumed the contours of what would be the rule for most of the twentieth century. Hell was no longer the subject of serious theological discussion and eventually disappeared even from folk belief, except perhaps for that of the most conservative Christians. In the wake of its demise and with the rise of a more materialistic view of the person, the idea of an immortal soul lost wide acceptance. Many people still believe in heaven, but it is no longer the subject of serious intellectual debate. Leading theologians, such as Reinhold Niebuhr (1892–1971) and Paul Tillich (1886–1965), even pronounced their hesitations about eternal life. Admittedly, systematic theologians have not given up presenting new eschatological designs, but none has found success in the last decades of the twentieth century. Not surprisingly, mainline churches have stopped worrying about the afterlife, since their members are too much concerned with this life. It seems that the world of theology, of rational reflection on life after death, is no longer influential among common believers.

Relection on life after death has not broken down completely, however. Among adherents of the so-called New Age there is a new interest in the soul, which is considered to be a part of the Higher Self, the New Age notion of an interface between the Universal Mind, or God, and the individual personality. It is the soul that continuously creates new lives and chooses its present incarnation. In other words, there no longer is a definite "Beyond" as the final resting point, but the soul is perpetually en route towards its spiritual perfection via reincarnation.

Finally, life after death has come once again to the fore in discussions of so-called near-death experiences, as first collected in the 1970s by Raymond Moody, an American philosopher turned psychiatrist. In these experiences, which relate a visit to the hereafter, the idea of a life after death seems to reflect widely ruling modern ideas: the dead go to heaven, but God is no longer there; the soul is not mentioned, and neither is hell or judgement. Scholarly discussions concentrate on the nature of these experiences, the age of those who have these visions, and the medical circumstances allowing such visions. Yet serious scholars no longer discuss these visions as testimonies of a postmortem existence. It seems that after a 2,500-year discussion, the problem of life after death has largely been abandoned.

See also DARWIN, CHARLES; HUME, DAVID; REINCARNATION; SOUL; THOMAS AQUINAS; TRANSMIGRATION

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JAN BREMMER

LIFE, BIOLOGICAL ASPECTS

Biologically, life, as contrasted with death or with nonliving objects, is an evident fact but difficult to characterize precisely. Living organisms are self-maintaining systems; they grow and are irritable in response to stimuli. They resist dying. They reproduce. The developing embryo is especially impressive. Organisms post a defended, semipermeable boundary between themselves and the outside world; they assimilate environmental materials to their own needs. They can be healthy or diseased. Some accounts claim that the minimal form of autonomy necessary and sufficient for characterizing biological life is what is termed autopoiesis, literally self-making. Some defense of a "self" (a somatic self, having to do with the body, rather than a psychological self) is thus required.

Living organisms gain and maintain internal order against the disordering tendencies of external nature. They keep recomposing themselves, while inanimate things run down, erode, and decompose. Organisms pump out disorder. Life, as physicist Erwin Schrödinger notes in his 1945 work, *What is Life?,* is a local countercurrent to entropy, an energetic fight uphill in a world that overall moves thermodynamically downhill.

The organism as system

The constellation of these characteristics is nowhere found outside living organisms, although some of them can be mimicked or analogically extended to products designed by living systems, such as computers, and some are found in spontaneous abiotic nature. A crystal reproduces a pattern and may restore a damaged surface; a planetary system continues in an equilibrium; a volcano may grow in countercurrent to entropy. A lenticular altocumulus cloud, formed as a standing wave over a mountain range, is steadily recomposed by input and output of air flow. A target-seeking missile adjusts its course by environmental feedback. Computers are cognitive processors and can be running well or poorly.

The know-how for life is coded into genetic sets, which are missing in minerals, volcanoes, clouds, computers, and target-seeking missiles. An organism is thus a spontaneous cybernetic system, self-maintaining with a control center, sustaining and reproducing itself on the basis of information about how to make its way through the world. There is some internal representation that is symbolically mediated in the coded "program" and metabolism executing this goal, a checking against performance in the world, using some sentient, perceptive, or other responsive capacities by which to compare match and mismatch. On the basis of information received, the cybernetic system can reckon with vicissitudes, opportunities, and adversities that the world presents.

Organisms employ physical and chemical causes, but, distinctive to life, there is "information" superintending the causes. This information is a modern equivalent of what Aristotle (384–322 B.C.E.) called formal and final causes; it gives the organism a telos, or end, but not always a felt or conscious end-in-view. Formerly, biologists looked for entelechy, some distinctive component in organisms not found in merely physicochemical systems. Although entelechy was never found, the major discovery of biologists in the last half century has been massive amounts of information coded in DNA, a sort of linguistic molecule.

Living organisms impose a code on four nucleotide bases strung as cross links on a double helix. A triplet of bases stands for one of the twenty amino acids, and by a serial "reading" of the DNA, "translated" by messenger RNA, a long polypeptide chain is synthesized, such that its sequential structure predetermines the bioform into which it will fold. Ever-lengthening chains are organized into genes. Diverse proteins, lipids, carbohydrates, enzymes—all the life structures—are thus "written into" the genetic library.

The DNA representing life is thus, to continue analogies, a "cognitive set," not less than a biological set. Organisms use these molecular positions to code the information necessary for life. In this sense, the genome is a set of conservation molecules. The novel resourcefulness lies in the epistemic content conserved, developed, and thrown forward to make biological resources out of the physicochemical sources. The presence of this executive program is often said to be cybernetic, a word recalling a governor or helmsman. An open cybernetic system is partly a special kind of cause and effect system, partly a historical information system discovering and evaluating ends so as to map and make a way through the world, and partly a system of significances attached to operations, pursuits, resources.

Threshold of life

DNA codes a life that is carried on not merely at the level described above, but at the environmental, phenotypical level. What occurs at the level of molecular biology manifests itself, via a complicated translation and interaction from genotypic to phenotypic levels (i.e., from the microscopic level of the genes to the macro level of the whole organism). This translation occurs at the native ranges, where such life is selected for or against as it is defended in its environment. With this process in mind some analysts to define as alive whatever is subject to natural selection, thus presuming also mutation. These features typically do characterize life. Critics of this definition respond that some things (such as viruses or groups of organisms) are subject to natural selection but are not alive. Also, life sometimes continues with much reduced natural selection. This is seen in human in their cultural environment. This phenomenon is also witnessed in clonal organisms that are all genetically identical or in relatively constant environments where most genetic changes result from mutations that are categorized as drift (i.e., functional changes that neutral to survival, neither beneficial nor detrimental).

Various thresholds or borderlines of life are disputed. A person may be considered "brain dead," although somatically the heart is still beating (often with a mechanical respirator). Many biologists hold that viruses are not (fully) alive, but are anomalous self-reproducing DNA fragments that parasitize living cells, largely borrowing most of their vital metabolisms from the host cell. Viruses are not self-contained, not cellular, but must be contained within other selves and cells. Computer advances have raised the possibility of "artificial life," with debates about what would count as a living computer, or perhaps as a living program, within a computer. Some organic molecules are known from space, but no extraterrestrial life is yet known. Scientists, philosophers, and theologians speculate, often intensely, about whether such life is likely to be present.

See also LIFE, RELIGIOUS AND PHILOSOPHICAL ASPECTS; LIFE SCIENCES

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HOLMES ROLSTON, III

LIFE, ORIGINS OF

Fossilized microbes or their chemical traces have been found in the oldest rocks on Earth. These rocks, which are about 3.8 billion years old, draw a picture of the structurally complex and metabolically sophisticated microbiota that already existed at that time. This leaves for the emergence of living things on Earth only a relatively short period of less than three hundred million years. During that period, complicated metabolic pathways must have developed. How?

Many religious as well as philosophical ideas assume that the interference with matter by a creative force or a creator results in the appearance of self-replicating life. Often the teleological character of living things in combination with a lack of understanding of natural processes leads to the conclusion that life is, in principle, "not of this world." In contract, the materialistic philosophical tradition interprets life as the most refined form of self-organizing matter.

It is an enormous intellectual challenge to explain the transition from lifeless chemistry to biology. The possible scenarios for this transition push scientific theories, worldviews, and the imagination to their limits. The following questions need to be answered. How is it possible that the beautifully well-balanced and encapsulated web of interaction that constitutes a living cell arose unintended from abiotic building blocks? How did its metabolism evolve? How could it happen that all the information that a parent cell needs to reproduce itself in the form of progeny was written in the chemical letters of the DNA molecule? And what was the first step that linked information (DNA) to function (proteins)? None of these questions has yet been answered by experimental evidence, however, numerous theories propose plausible scenarios that could result in the appearance of all living things. In addition, chemists have recreated chemical reactions that result in the formation of numerous of the most essential organic building blocks, such as amino acids and nucleic acids. Chemists have so far failed, however, to reconstruct the abiological formation under prebiotic conditions of the molecule ribose, which is essential to life as the backbone of DNA and RNA molecules. It has also been shown that amphiphilic compounds, such as fatty acids, spontaneously self-assemble and form encapsulated spheres, which separate into an "inside" from an "outside," and thus represent the origin of *compartimentation*. The most prominent of theories about the origin of life will be presented in this entry, and some of the problems related to the models will be discussed.

The Oparin-Haldane model

The Oparin-Haldane model of prebiotic evolution and cell formation was developed independently during the 1920s by British biologist J. B. S. Haldane and Soviet biochemist Aleksandr Oparin. According to the Oparin-Haldane model, organic molecules were formed in the reducing atmosphere of the early Earth and then accumulated in the oceans, where a thin organic solution, the so-called primordial soup, formed. In addition to the atmospheric source of organics, the theory also considers input from comets and certain types of meteorites as an important source of organic building blocks.

In the primordial soup, amphiphilic molecules, such as fatty acids, continuously formed small fatty droplets called *coacervates*. During self-assembly these coacervates encapsulated a small amount of the soup, which supplied them with building blocks and energy sources. Further coacervates grew by incorporation of more amphiphilic compounds until they became large enough to be unstable, resulting in coacervate division. Even during the coacervate state, competition and selection among these structures were driving a progressive evolution. The Oparin-Haldane model assumed that the original way of feeding was *heterotrophic,* which means that the cellular structures grew by assimilation of prefabricated organic building blocks that also served as energy sources. Overall, the model supposes that cells came first, proteins second, and genes third.

The major contribution of the Oparin-Haldane model to the scientific origin of life debate was to link abiotic chemistry to the history of life. Haldane and Oparin broke with the powerful and experimentally supported paradigm of the French chemist Louis Pasteur that only life can be the source of new life and that life can not arise spontaneously from a nonliving material. Despite its narrative eloquence, the Oparin-Haldane model has serious scientific shortcomings: (1) The atmosphere of the early Earth was most likely different and less reduced than the Oparin-Haldane model requires for the synthesis of all the molecules necessary for prebiotic synthesis; (2) The intensity of ultraviolet radiation on the surface of the ocean would have constrained the accumulation of prebiotic molecules. In addition, complex molecules are less stable when dissolved in water, which seriously limits the formation of information and function-carrying macromolecules like RNA, DNA, and proteins; and (3) Prebiotic synthesis produces only small amounts of the desired organic compounds.

Template-based models

Clay-based template. Some scientists have proposed alternatives to the primeval soup model that can be summarized as *template-based* origin of life models. One of them, the *clay-based* origin of life theory, attributes to microcrystals of clay both an informational and a catalytic function. According to the theory, the matrix of clay contains a regular array of ionic sites, which are occupied by irregularly alternating patterns of metal ions such as magnesium or aluminum. The pattern of alternating metal ions contains information similar to the patterns of nucleic acids in DNA or RNA molecules. Organic molecules, which are present in the environment of clay crystals, may have been attracted by the electrostatic potential of the metal ions and positioned themselves in a way that facilitates a chemical reaction between the adsorbed molecules (i.e., those attached to the surface). In this scenario, clay surfaces have a catalytic function comparable to those of proteins. The information content of clay crystals was transferred to a new generation of crystals by accreting silicate and metals from the surrounding water and by reproducing the original pattern of metal ions associated with the new clay matrix. It may be that clay-based life existed for millions of years but was finally out-competed by RNA-based life, which had much better chemical properties, and all traces of these original clay-based life forms disappeared.

The clay model has two major strengths: (1) A variety of clays do in fact catalyze the polymerization of organic compounds under conditions that are realistic for the early Earth; (2) Stereospecific amino acid binding and polymerization have been demonstrated. Among several weaknesses of the clay model are: (1) a lack of environmental settings that support clay evolution and stability; (2) the late development of *cellularization*; and (3) the inability of the model to explain the relation between microorganisms and the presumed traits of early life.

Pyrite-based template. While the clay-model, like the Oparin-Haldane model, assumes that the organic molecules necessary for cell formation and polymerization were provided by a thin soup in the surroundings of the clay crystals, the *pyrite-based* template model rejects this concept and postulates the inorganic origin of life instead. In this scenario, organic molecules were synthesized in high temperature environments comparable to hydrothermal vents on the surface of growing pyrite crystals, which form from the reaction between ferrous sulfide and hydrogen sulfide. During the process of pyrite formation, electrons are released, which, due to the catalytic properties of the pyrite crystal, can be transferred directly to carbon dioxide. (In a later version of the theory based on experimental results, carbon monoxide replaced carbon dioxide.) In this process, simple reduced compounds like formic and acetic acid were formed. In addition to their catalytic properties, the positive charge of pyrite crystals allows them to retain the newly-synthesized negatively-charged organic molecules. Consequently, organic molecules accumulated on the pyrite surface, steadily coating it with an organic layer in a process of cellularization. It can thus also be attributed a selective property of the surface charge of the pyrite crystal: Molecules that do not stick to the crystal are lost by diffusion and do not participate in further processes. As simple molecules polymerized on the surface of the pyrite crystal, gradually more complex molecules were formed, including a membrane-like layer, which enclosed the pyrite crystal. In the pyrite model, metabolism came first. For a long time, competing cell-like structures resulted exclusively from the structuring properties of the pyrite crystal, which both served as the energy and electron source for carbon fixation, and as a cellularization nucleus without the involvement of information carriers such as RNA and DNA.

Unlike the other models, it is a major concern of the proponents of the pyrite model that all specific predictions, at least in principle, stand up to experimental investigation. Hitherto, several predictions deduced from the pyrite model have been verified experimentally. In addition, the presence of iron sulfur clusters in the catalytic centers of ancient enzymes has been interpreted as the remains of a pyrite past. Still the model is not without problems. Most of the criticism concerns the environmental sites where pyrite life potentially could have occurred. Hydrothermal vents are relatively short-lived structures, which limits the time available to pyrite-based life formation at a particular site. In addition, the high temperature, which may be required for some types of synthesis, may effect other processes negatively. Another serious concern addresses the phosphate necessary for the initial surface binding of organic compounds to pyrite. Because of precipitation, typical vent environments are strongly depleted in phosphate. If the same holds true for ancient vent systems, it is difficult to explain how life could have originated there.

RNA-world model. The most popular scenario of the origin of life is the so-called *RNA-world model,* which elaborates on the Haldane-Oparin theory. The RNA-world model proposes that RNA molecules were the precursors of proteins as catalysts and of DNA as information carriers. This concept gained support when the catalytic properties of modern RNA molecules were demonstrated. Proponents of this theory introduced the term *ribozyme,* which stresses the functional similarity of RNA molecules to protein molecules, in addition to their already established role as informational molecules. The following scenario has been outlined for the development of the RNA world: (1) Short RNA molecules formed from random combination of mononucleotides; (2) Some oligonucleotide structurally include the potential of catalyzing the synthesis of complementary copies of themselves, with the chemical energy for the process provided by reactive molecules combined with the mononucleotides; (3) RNA molecules developed that catalyzed their own synthesis, and as a consequence evolution by natural selection became possible.

Stage three in the RNA-world scenario can be summarized by the so-called hypercycle model, which links related RNA molecules in the form of a catalytic cycle. The interaction between RNA molecules was already characterized by a selection-constrained evolution potential. Steps one and two of the RNA-world model have some shortcomings which have yet to be overcome. These shortcomings include the synthesis of important components of the RNA molecule such as sugar ribose and reactive phosphate molecules. It has been proposed that not RNA itself but a simpler RNA-like molecule was at the origin of life.

Self-organizing models

As an alternative to the template-based scenarios described above, scientists have developed a theoretical framework that is based on the concept of *catalytic closure.* Here life started as *autocatalytic* sets of molecules, which means that all the molecules within the set catalyze their formation, and also catalyze the formation of their catalysts. A hypercycle is based on the interaction between RNA molecules. In principle, protein-based cycles or cycles which combine different types of macromolecules may also exist.

The scientific theories of the origin of life presented here are only preliminary and require numerous experiments and sophisticate modeling before they can gain general acceptance. At best, researchers will find answers to most of the open questions. At worst, they will end up producing more questions than they answer. The consequences of such scientific concepts for philosophical and religious traditions are likely to be marginal as the latter address mainly phenotypical expressions of living processes rather than "happenings" in the distant past.

See also AUTOPOEISIS; BIOLOGY; EMERGENCE; EVOLUTION, BIOLOGICAL; LIFE, RELIGIOUS AND PHILOSOPHICAL ASPECTS; LIFE SCIENCES

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KAI FINSTER

LIFE, RELIGIOUS AND PHILOSOPHICAL ASPECTS

Life is literally a biological term but extends by metaphor across a spectrum of key concerns in philosophy and religion. Life is a perennial experience, prescientific and universal in cultures ancient and contemporary, though recent advances in the biological sciences have recast classical ideas about life in new perspectives. By some accounts, molecular biologists decoding the human genome have discovered the "secret of life"; by other accounts evolutionary biologists have discovered the "secret of life" in natural selection. Philosophers, ethicists, and theologians reply with claims that, though science may teach much descriptively about life, it cannot teach how to value life and what one ought to do.

From the dawn of religious impulses, in the only animal capable of such reflection, this vitality has been experienced as sacred. Such experience has often been fragmentary and confused, as has every other form of knowledge that humans have struggled to gain, but at its core the insight developed that religion was about an abundant life, about life in its abundance. Classical monotheism—to take the Hebrew form of it—held that the divine Spirit or Wind (Greek: *pneuma*) breathes the breath of life into the dust of the earth and animates it to generate swarms of living beings (Genesis 2:7). Eastern religious forms can be significantly different: *Maya* spun over Brahman, or *samsara* over *sunyata*; but they too detect the sacred in, with, and under the profuse phenomena of life.

If anything is sacred, life is sacred. For theists, life, above all, is a gift from God. Elemental necessities, such as bread, water, blood, breath (*pneuma*), and birth are often taken up as symbols in religions. Native traditions may regard Earth, soil, waters, everything as alive. Scientists may now dismiss this as an innate tendency to be animistic, to ascribe living properties to inanimate forces. But quite sophisticated philosophical systems, such as panpsychism, pantheism, and forms of idealism, have held that ultimate reality is organic or spirit-like.

Organic life

Philosophical and religious concerns about life can be broadly divided into those involving life generically and those focusing on human life. One intense debate arising in the last half century has been over intrinsic value in life, whether organisms have value in themselves, and not simply instrumental value for humans. The background to this debate is an Enlightenment tradition of a value-free nature, seemingly plausible in the inanimate world of stars, asteroids, rocks, or dirt, an account continued by many biologists in a mechanistic biology, which views organisms as nothing but machines. However, contemporary biologists have not only described but come to celebrate the diverse array of forms of life (species, families, phyla), to systematize these, and then lament that humans are placing so many of them in jeopardy. Conservation biology today is as dominant and remarkable as is molecular or evolutionary biology.

The panorama of life on Earth, biologically described, raises issues of whether the species can also be ranked or graded for their worth. Levels of life move from microbes to multicellular plant and animals, with "higher" animals sentient, many of them capable of acquired learning during their lifetimes, and the "higher" of these enjoying psychological experiences, the "highest" of all human life with self-conscious experience, capable of generating meaningful communities gathering into cumulative transmissible cultures. Other thinkers, claiming a more egalitarian and less biased account, object to such hierarchy and anthropocentrism, advocating a biocentrism where all are valued with respect to their multiple and differing achievements and skills, including humans, but not preferential to humans. The capacity for photosynthesis is as valuable on Earth as is the capacity for ethics.

Darwinian natural history reveals an ambiguity in life, often taken to be problematic. Life is a ceaseless struggle; new life is generated by blasting the old. Darwinians may focus on the survival of the fittest, accentuating the competition in life, famously described by the nineteenth century English poet Alfred Lord Tennyson as "Nature, red in tooth and claw." Charles Darwin as well portrays connectedness in life, common ancestry, survival of the best adapted, life support in ecosystems, life persisting in the midst of its perpetual perishing, life generated and regenerated in spectacular biodiversity and complexity, with exuberance displayed over 3.5 billion years, an "abundance of life." Such a view of life echoes ancient religious motifs: Life is a table prepared in the midst of enemies, green pastures in the valley of the shadow of death.

Debate continues over whether the natural history of life on Earth is orderly, probable, inevitable, or contingent; over what mixture of law and openness characterizes it; and whether biological processes are adequate to account for life's origin and evolving diversity and complexity. Molecular biologists have discovered hitherto unsuspected intricacy and complexity at the molecular level, also endorsing life with its unity in diversity, and leaving as intense as ever the religious concerns about what to make of life, and what abundant life is possible and appropriate for humans.

The distinctiveness of human life

Turning to human life, a recurrent issue is whether and how human life is distinctive. The biological sciences evidently supply connections; humans differ in their protein molecules from chimpanzees by only a fraction of a percent. But the startling successes of humans doing biological sciences can as readily prove human distinctiveness: Chimpanzees have no capacities for cumulative transmissible cultures leading to a science by which they can decode their own genes, much less can they debate the ethics of cloning or have their religious convictions challenged by reading Darwin's *Origin of Species*.

Various human activities have their parallels and precursors in animal behaviors; animals get sleepy, angry, suffer pains, enjoy pleasures. Equally, myriads of human capacities are sui generis; animals do not pray, or seek forgiveness for sin, or worry whether the theory of relativity relativizes ethics. Humans are persons, made (as theologians like to say) "in the image of God." They have *Existenz* (as the Existentialists say). Humans anticipate death; they sense their finitude; they face limit questions. They know guilt, forgiveness, shame, remorse, glory, pride. They suffer angst and alienation. They build symbols with which they interpret their place and role in their world. They create ideologies, affirm creeds, and debate their rights and responsibilities. They are capable of religious faith and the worship of God. Many of them sense the sacred, worry about communion with the ultimate, or atonement of their sins. All of this can be summed up in the one word: spirit. In this life of the spirit, humans, latecoming on the planet, remain remarkably distinctive from the other millions of species, indeed the billions that have come and gone over evolutionary time.

One distinctive characteristic of human life is its brokenness, and here the religions classically offer salvation, or the good life. "I have set before you life and death, blessing and curse; therefore choose life" (Deuteronomy 30:19). Jesus says "I am the way, the truth, and the life" (John 14:6). The metaphor may be of new life; one is born again, or regenerated. This re-forming of life appears to many philosophers, ethicists, and theologians to be the area in which biology has so little purchase—the "ought to be"—however much biology has decoded what is describing the metabolisms and evolution of life, or perhaps found so-called *selfish genes* that dispose our behavior.

The relevance of religion to scientific explanations

Humanists may resist claims that biology explains religion, finding the secret of life in genes or in natural section, or finding that religion is (nothing but) a mythical belief system that favors survival. Theologians turn the tables, arguing that religion is needed to explain biology, that the prolific genesis of life on Earth, documented in natural history, generates religious responses. The prolific earthen fertility, or generative capacity, in which humans find themselves immersed, is what most needs to be explained. Humans alone confront the ethical duty of appropriate respect for such life, including their own human life. Nothing in biology settles questions about the meaning of life.

Advances in our biological understanding of life, as well as medical and technological capacities to intervene, have raised new issues that involve the beginning and ending of life (such as cloning, abortion, and euthanasia). Other advances make life more of a commodity (as with farm agriculture, genetically modified crops, stem cell lines, or patented genes).

Ethicists frequently claim that our concern ought to be for quality of life, not just life—and again religious convictions can seem as relevant as biological facts. Biology can set some standards for whether organisms are flourishing or diseased; quasi-evaluative terms such as "health" or "integrity" do have a foundation in biology. Beyond that, the quality of life demands evaluative judgments about right and wrong, censure and blame, good and evil. Life requires choosing a lifestyle. Life demands respect, and this respect passes over, often imperceptibly, to reverence. Though a secular science, biology invites an inquiry into the sacred.

Life has death as its opposite, or complement. Life survives death on Earth by reproducing biologically. Religions ask about the quality of life on Earth, but the inevitable earthen death of individuals raises the question of life after death, of eternal life, of what survives the bodily demise of an individual. Religions answer this question variously. Some, especially Eastern religions, suppose rebirth and reincarnation, a sequence of lives on Earth or in other worlds. Western monotheism, in Islam and Christianity, has favored life on Earth consummated in life in heaven, perhaps by a continuing immortal soul, or spirit, outliving the body, perhaps by a resurrection of the body. A perennial faith expects continued life in the spirit gathered into the Divine Spirit.

See also LIFE, BIOLOGICAL ASPECTS; LIFE SCIENCES

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HOLMES ROLSTON, III

LIFE SCIENCES

The life sciences, defined as biology and related subjects, encompass the detailed study of living organisms, which are broadly distinguished from inorganic matter through the capacity for growth, function, and change preceding death. Biology is not limited to physiology, the study of the growth and function of living organisms. It also includes the study of biochemical reactions taking place in particular cells of particular organs. At a physical level, biophysics considers, for example, electrical changes taking place across membranes. Even more specific is the field of molecular biology, which attempts to unravel the changes that occur in molecules during biochemical reactions. Genetic science is the study of molecules that act as templates of information for certain biochemical reactions and that are passed on to the next generation. Yet the life sciences include the study of more than just the interior of living organisms and the biological reactions in the cells of living organisms. The life sciences also include ecology, the study of the exterior context of particular environments and the interrelationships between species. More broadly, animal behaviorists examine the way animals react to environments, and psychologists explore the possible reasons for this behavior.

The different life sciences pose challenges to theological and religious interpretations of reality. Put simply, if the life sciences can offer explanations for the way life functions on Earth, there is no need to invoke a divine creator. Is it possible to recover the belief held in the seventeenth century that all aspects of creation are the works of a divine mind? Or, if one accepts that God creates the world through the processes of biology, how far might it be possible to take such knowledge into human hands? Do people have the right to become co-creators with God in shaping the course of their own evolution and that of other species? One's view of ethics will depend on the particular view of God that one presupposes. Another question often asked is how far the scientific understanding of life is equipped to answer the complex ethical questions that have emerged in contested areas such as genetics and environmentalism. In these scenarios it may be that theology has more to offer than simply a response to the problems that science poses to its own fundamental beliefs.

Exploring the science

Having given a rough sketch of the range of sciences included in the concept of the life sciences, it is necessary to explore the task and presuppositions of the different sciences in order to understand their theoretical interrelationships. Molecular biology, for example, made a dramatic contribution to the study of genetics by defining the double helical structure of deoxyribonucleic acid (DNA) found in chromosomes. This discovery, published in 1953, is attributed to James Watson and Francis Crick, although Rosalind Franklin and Maurice Wilkins also provided vital experimental data. DNA consists of two strands of sugars and phosphates that are joined together by pairing of particular bases attached to the sugars. The pairing of bases is always the same, adenine with thymine and cytosine with guanine. The DNA unravels once a gene becomes active so that a particular section of DNA codes for a particular carrier nucleic acid, and thence to a particular protein. Moreover, the DNA can replicate itself by unwinding, after which each single strand pairs with another.

Once scientists defined the structure of DNA, it became possible not only to understand the reasons for genetic diseases, but also to develop ways of changing DNA structure by cutting or adding particular sections of DNA to the existing template. The practical science to which genetics relates most naturally is medicine, though it also has implications for commercial use in biotechnology.

It is possible to think about the sciences as operative at different levels in the study of living organisms. At the most fundamental level, molecular biologists examine changes in molecules during particular reactions. However, some would argue that the physical changes taking place are even more primary than this, so that changes in physical fields are coincident with certain chemical and molecular changes. The movement of charged molecules or ions across membranes, for example, is accompanied by electrical changes in the membrane. Biophysicists are interested in unravelling the details of such changes. At the next highest level, cell biologists explore reactions taking place at a cellular level, for example, the biochemical interchange between different parts of the cell or organelles. Cells make up organs, and the deciphering of the function of different organs in relation to the overall health of the organism delineates the field of physiology. For example, the way organisms use nutrients is the concern of physiologists. The idea of nutrients is suggestive of the interaction between the organisms and their environment, and one of the concerns of ecologists is nutrient exchange between species.

Ecology is important as far as the human sciences are concerned because it bears on human interrelationships with other living creatures. At the broadest level, geophysiologists examine the relationship between living creatures and the planet as a whole. This science, provocatively named the *Gaia Hypothesis* by James Lovelock in 1969, suggests a different way of doing science, one that, like ecology, examines relationships, rather than biochemical or biophysical reactions. Lovelock's hypothesis is that the Earth's relatively stable temperature and the gaseous composition of its atmosphere are not accidental; rather the sum total of all living things, or *biota,* directly contribute to this stability. His hypothesis is difficult to prove, so it has been marginalized by the scientific establishment.

The history of the way life emerged on the planet looks to fundamental questions about the origins of life itself. Charles Darwin's theory of evolution explored the biological processes that underlie the diversity of life on this planet. His theory of natural selection states that the survival of individuals in a species depends on those characteristics that render them most fit for a particular environment, and therefore most able to have the most offspring. The scientific study of genetics has defined more precisely the mechanism through which these characteristics are inherited. Evolutionary ideas link genetic science with ecological science. On the one hand, the history of the evolution of species depends on genes passing from one generation to the next, the so-called selfish gene theory exemplified most famously by biologist Richard Dawkins. On the other hand, the ways genes are expressed depend on a particular environment, so that the combined effect of genetics and environment makes up the *phenotype* of the individual organism. Lovelock's hypothesis challenges the assumption that organisms are always adapted to their environment by suggesting that the activities of organisms in and of themselves not only influence but also regulate their environment. Most biologists, however, accept Darwin's basic theory of natural selection.

The life sciences are not only concerned with the history or origin of life on Earth—they also have their own story of development. Ecology, for example, in the early part of the twentieth century considered its task to be the examination of succession of plant communities that established particular habitats, niches, or homes for other species. After 1945 ecologists began to look at the relationships between species in terms of energy exchange, all contributing to a particular ecosystem. Ecosystems lend stability and equilibrium to communities of organisms, however, ecologists have become less convinced that ecosystems function as stable communities. Instead of balance there is disturbance; instead of equilibrium, there is a fluid landscape of different, loosely assembled, environments. In addition, the scale of measurements used is important; ecology could be studied at the level of the leaf, canopy, patch, or forest, moving up the scale of organization. Higher up the scale different emerging properties appear. Debates exist concerning the degree to which these properties are simply dependent on activities at the lower levels of organization (*bottom-up causation*), are unique to their own level, or perhaps even a result of activities further up the scale (*top-down causation*). Emergent properties are still open to scientific consideration. The philosophical idea that these properties consist of the addition of a unique substance known as *vitalism* is rejected by contemporary science. Some writers, by their suggestion that Gaia is a living organism, have interpreted Lovelock's ideas in such a way that it comes close to this view.

Exploring issues in science and religion. Darwin's theory of evolution poses challenges to the Christian idea of divine creation and design. The way theologians respond to this challenge is likely to influence the way they approach the life sciences in general. For example, if Darwin's theory is rejected, then it is likely that a conservative approach to genetic science will ensue, and there will be resistance to most, if not all, genetic engineering. According to this view, the diversity of species on the planet is the result of divine fiat associated with the story of Genesis.

Those in broad agreement with Darwinian science may either retain a classical model of God as creator of the world, with God creating through evolutionary processes, or they embed their view of God more specifically in biological processes themselves, so that God evolves with biological change. While both views can support technological change, the emphasis is different. For Celia Deane-Drummond, for example, God may be viewed as divine wisdom, which creates the world in love through wisdom. Hence the diversity of life is affirmed as the gift of God. Each species needs to be given respect on the basis that each is loved by God, even though God has allowed changes to evolve. Although the classical view of God is associated with an understanding of God as omnipotent and omnipresent, it is possible to affirm the transcendence of God without assuming a static and remote model of who God is. If changes are to be made in the genetic makeup of species, then these changes need to take into account the particular telos or purpose of each individual species as far as it is possible to understand it. Moreover, those who do attempt to re-order the natural world via biochemistry need to be aware that it requires a particular gift, namely the gift of wisdom and discernment, in order to assess the limits of such attempts.

The alternative view perceives God not so much as "other" to creation, but as one who allows creation to emerge and become itself through divine activity. Accordingly, for Philip Hefner, humans can become co-creators with God and look to their individual freedom and individuality as the basis for change. Just because humans have more freedom does not mean that God is in some way restricted in freedom. Genetic determinism is rejected by many authors, such as Ted Peters, who argue that human beings are more that just products of genetic activity. As co-creators humans have the authority to make changes to the genetics of human and other species. The suffering of those with genetic diseases engenders compassion that calls for action. The failure to contribute to such a change when the knowledge exists amounts to apathy, rather than arrogance. There are important issues in human genetics, but the issues depend more on analysis of the risks and benefits of particular actions, rather than on any fundamental resistance to change. Many see the responsible re-ordering of the world as a mandate for human beings; the gift from God is the gift of science and technology.

Both alternatives discussed above are in broad agreement about the limitations of extending biological understanding of reality to cultural experience. Stated simply, sociobiologists find in Darwin's theory of evolution reasons for the emergence not just of physical traits, but also of human character attributes. The philosopher Holmes Rolston III has argued convincingly that attempts to trace complex ethical characteristics to genetic changes are simplistic. He believes that although the tendency to socialize may have a genetic component, the content of moral laws cannot arise only from genes. However, while the first view would see the shape of such moral law as taking its orientation from the eternal law of God, the second view lays emphasis on the moral freedom of individuals to devise their own laws, where the will of God in this case is somewhat diffuse because God is part of the process of change. It is also not clear according to this view what contribution theology can make to debates over genetic change, other than showing that it is possible to affirm science and be Christian.

There are also wider environmental issues that impinge on genetic science when it is applied to biotechnology. Important questions include the effect of introducing new genetic varieties on human communities set in ecological communities. Plant and animal breeding has taken place for many millennia, but the tools now available in genetic science allow genes to be transferred across species in a way that is unique. What once took years can now be achieved in days. Many ecologists are concerned about the loss of diversity and other possible damaging influences on fragile ecological communities. Yet the understanding of ecology as inclusive of human activity and in flux, rather than equilibrium, needs to be taken into account. There is a clash between those in the biotechnological industry, keen to introduce change for the sake of individual benefits such as pest resistance, and those more inclined to consider the wider impact of such changes on natural habitats. Theologians are being forced to consider the complexity of these social issues in deliberations about genetics and environment. Some suggest that complexity itself challenges the merit of secular approaches to ethics that simply look to the consequences of actions in terms of risks and benefits. Might there, indeed, be a way of reshaping the direction of science so that it does not look at problems narrowly, but considers social issues and the wider context of public debate? Some suggest that the answer is a return to a more holistic view of science, one that seeks knowledge not just as information, but in the broader framework of a search for wisdom.

See also CREATED CO-CREATOR; DNA; ECOLOGY; EVOLUTION, BIOLOGICAL; GAIA HYPOTHESIS; LIFE; LIFE, ORIGINS OF; LIFE, RELIGIOUS AND PHILOSOPHICAL ASPECTS; SELFISH GENE; SOCIOBIOLOGY

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CELIA DEANE-DRUMMOND

LINGUISTICS

See LANGUAGE

LOCALITY

Locality is a feature of the world that is suggested by the experience that local causes produce local effects. In quantum mechanics, however, the EPR Paradox conceived of widely separated situations entangled by virtue of their quantum histories, and it is possible for a quantum measurement to have a nonlocal effect. It has sometimes been suggested that nonlocality might form a basis for telepathy or some form of faster-than-light signaling or travel. However, it can be shown that within quantum mechanics it is not possible to transfer information faster than the speed of light by exploiting quantum nonlocality. No two quantum mechanical measurements can be connected to each other by a faster-than-light signal.

Albert Einstein's (1879–1955) General Theory of Relativity requires local behavior in ways that Newton's theory of gravity does not. In Isaac Newton's (1642–1727) theory there exist mysterious gravitational forces that act instantaneously over unlimited distances in space (for example, the gravitational force of the sun on the Earth). In Einstein's theory there are no instantaneous nonlocal gravitational forces. Everything acts locally. The presence of mass or energy in space makes space curved, and all bodies move in response to the local curvature of space that they encounter locally, not in response to long-range, nonlocal forces of attraction.

Locality played an important role in the development of Western science. Most early science in the West was nonholistic in the sense that it maintained that the world could be analyzed locally without having to understand the whole of the universe. By contrast, Eastern holistic philosophies were handicapped in the development of a successful working theory of nature because they held strongly to a holistic view of the world. There has been debate about the resonance between the holistic nature of some parts of modern physics, notably quantum mechanics, chaos, and complexity, and early Eastern holistic philosophies. It is clear that a local, nonholistic, largely reductionist outlook is advantageous in beginning a successful scientific enterprise. While there undoubtedly are holistic aspects of the world, they are most effectively understood after having understood the local aspects.

See also EPR PARADOX; PHYSICS, QUANTUM; RELATIVITY, GENERAL THEORY OF

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JOHN D. BARROW

M

MAIMONIDES

A twelfth-century rabbi and community leader, philosopher and physician, Maimonides was fascinated by the relation between science and religion from his earliest days. A polymath by inclination, he needed first to master the sciences then extant, including logic, mathematics and medicine, before being able to assess their relation to his Jewish faith. Indeed, he insisted on philosophy's mediating role in the mutual illumination of faith and reason, notably with regard to creation.

Early life and influences

Mosheh ben Maimon, called Maimonides by Latin authors and known to the Arabic-speaking world as Musa ben Maimun, Moses son of Maimon, was born on March 30, 1135 C.E., in the city of Córdoba, Spain, where eight generations of his ancestors had served as rabbis and rabbinical judges. Capital of the Umayyad emirs and caliphs in Spain since the eighth century, Córdoba had remained even in their political decline the center of a brilliant, prosperous civilization in which Jews and Christians, as well as Muslims, were active participants. Young Moses himself was not to enjoy this cosmopolitan milieu much past his bar mitzvah, as the family was forced to flee their home in the wake of the Almohads from North Africa, who forbade Jews or Christians to profess their religion openly. Yet in the relative calm prior to the shattering of their world, the Jews of Spain had built an intellectual capital from which Maimonides was to profit immeasurably, even after the world that had produced it ceased to exist.

Poetry, astronomy, medicine, philosophy, scriptural exegesis, grammar, history, and mysticism were typically integrated into a comprehensive education. Moses's father, Maimon, led the family to Fez (in present-day Morocco), the very center of the Almohad movement, where they managed to survive for five years, only to move on to Palestine in 1165, where Maimonides journeyed to the site of the temple in Jerusalem to give thanks for the gift of this pilgrimage, and thence to Hebron, the traditional resting place of Abraham, who held a special place in Maimonides's vision of history, not only as the first spokesperson of a universal monotheism, but also as the first to base theological claims on arguments derived from reason. Since the rule of the Latin Kingdom of Jerusalem offered a less than favorable milieu for developing Jewish life and culture, the family proceeded to Egypt, where Maimon soon died, leaving his son to take up the roles in the community to which his learning entitled him.

Legal and philosophical writings

Remarkably, Maimonides continued his education under the stress of exile and travel, composing his commentary on the Jewish legal canon, the Mishnah, during the seven years of exile from his twenty-third to thirtieth years. Taking up residence in Fustat (Old Cairo), he was appointed judge of the rabbinical court and soon assumed leadership of the community. After the death of his brother and the loss of the family savings in a shipwreck, Maimonides took up the responsibility of supporting the family as a physician, practicing medicine until his death. During this time he was court physician to Saladin (c. 1137–1193), the Sultan of Egypt and Syria, as well as the entire court, leaving him little time to study and write, yet he accomplished both, along with adjudicating disputes within the Jewish community. The completion of his groundbreaking codification of Jewish law, the *Mishneh Torah,* around 1178, brought him even greater fame that his earlier commentary, and he was beset with requests for legal opinions from communities throughout the Islamic world.

At this time, however, he also encountered Rabbi Joseph ibn Judah Aqnin, who insisted Maimonides guide him into the logic, cosmology, theology, and philosophy of the Greco-Arabic tradition, so as to be able to converse with other learned communities in the Islamicate. Following a course of study as old as Plato's Academy in the fourth century B.C.E., Maimonides initiated his student into astronomy and mathematics, and then logic, and finally metaphysics, by using its tools to explicate the conundra the revealed texts often left to readers of the Hebrew scriptures. This series of exercise in biblical interpretation and philosophical exegesis was published in 1190 as the *Guide to the Perplexed.* It was immediately translated from Arabic into Hebrew, and then into Latin, where it served as a model for Christian thinkers like Thomas Aquinas (c. 1225–1274) to integrate assertions of faith with explorations of reason.

Science and religion

The most vexing issue turned out to be the claim of Genesis that time itself began with creation, whereas the prevailing philosophical view had long been of a universe emanating necessarily and without beginning from a single unitary principle. Maimonides established the model for addressing this conflict between the divergent claims of reason and of faith by using his philosophical acumen to show that the authority whom philosophers had invoked—Aristotle—had neither intended nor achieved a demonstration of the universe coming forth from a single unitary principle without beginning. And having shown that, he proceeded to delineate the anomalies in the actual universe, notably the errant path of the planets (or "wandering stars"), to point out that no set of logical principles could account for the actual ordering of the heavens, despite the elegance of the necessary emanation scheme. So, he said, it makes more eminent sense to posit a free creator, whose intentional ordering could explain what logic cannot.

This central bit of reasoning displays how his scientific acumen could be put to use to make it possible for believers to accept the words of Genesis at face value, yet he was also quick to insist that neither view could be proven. Moreover, where scriptural texts did conflict with proven tenets of reason, then they would have to be interpreted figuratively; since the divine reality could not be bodily, texts referring to the "Lord's mighty arm" would have to be read metaphorically. He was even prepared to read Genesis that way, foregoing a first moment of time for creation, but the absence of a valid demonstration of the prevailing philosophical view reduced it to the level of mere opinion—however widely held it had been, and so opened the way to a belief in scripture that was straightforward yet sophisticated. Such is the legacy that all religious traditions received from Maimonides, whose strategies were transmitted to the Christian world by way of Aquinas and others after him. In short, what seem to be conflicts between faith and reason, religion and science, may often be defused by a proper understanding of each domain, yet doing so requires an education and a sensibility as astute as Moses Maimonides's. As the celebrated Hebrew saying has it: "from Moses to Moses, there arose none like Moses."

See also CREATION; GENESIS; HISTORICAL CRITICISM; JUDAISM; JUDAISM, CONTEMPORARY ISSUES IN SCIENCE AND RELIGION; JUDAISM, HISTORY OF SCIENCE AND RELIGION, MEDIEVAL PERIOD; THOMAS AQUINAS

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MANY-WORLDS HYPOTHESIS

One of the fundamental interpretive problems of quantum theory arises from the fact that from any two or more states for a system one can create another state, their *superposition* (mathematically, a linear combination). Let s and s' be possible states for a system, corresponding to two different values, k and k' respectively, for the observable, O. (That is, they are mutually orthogonal eigenstates of O.) Their superposition, which is another possible state for the system, is denoted by $s + s'$. According to the standard interpretation of quantum theory, a system in the state $s + s'$ does not have the value k for O, nor the value k' for O, nor neither, but if O is measured on the system, the system will be found to have either the value of k or the value of k' for O.

The standard interpretation works in practice, but many physicists and philosophers find it to be unsatisfactory for a variety of reasons, not least because it contains the unanalyzed notion of "measurement." With minimal experience, it is easy to judge when to say that a measure of O has occurred, but upon what principle can such a judgment be made? No satisfactory principle has been offered. The other problematic feature of the standard interpretation is that it countenances physical systems that are literally indeterminate with respect to their values for observables such as "position." In other words, a physical system (outside of a context in which its location is being measured) can literally have no location (though if its location is measured, it will be found to have a location). The Many-worlds Hypothesis, which originally arises from work by Hugh Everett (1930–1982), is an alternative approach to interpretation that purports to dispense with the notion of measurement and to resolve the problem of indeterminacy.

The central idea behind the Many-worlds Hypothesis is that a state such as $s + s'$ in fact describes a multiplicity of distinct, independent, worlds, some in which our system is in the state s and others in which our system is in the state s'. In most versions of the Many-worlds interpretation, there are, in all, an uncountable infinity of worlds, divided amongst the various states appearing in the superposition (in our case, s and s') according to the probabilities attached to the various states. So if, according to the standard interpretation, a measurement of O on our system would reveal the value k with probability $\frac{1}{3}$, and k' with the probability $\frac{2}{3}$, then according to the Many-worlds interpretations, in $\frac{1}{3}$ of the worlds our system is in the state s, and so has the value k for O, and in $\frac{2}{3}$ of the worlds our system is in the state s', and so has the value k' for O.

It is important to keep in mind that the "worlds" of the Many-worlds interpretation are not the same as the "possible worlds" of philosophy. This point is clear in light of the fact that the philosopher's possible worlds need not obey the laws of quantum theory, while the single "universe" of the Many-worlds interpretation does obey the laws of quantum theory. In the Many-worlds interpretation, therefore, there is a single "actual" world in the philosopher's sense, but it consists of many distinct independent "realms of reality." However, in standard usage, these realms of reality are called *worlds.*

A variant of the Many-worlds Hypothesis, called the *Many-minds Hypothesis,* asserts that the multiplicity in question is not a multiplicity of worlds, but a multiplicity of distinct, independent, minds. Each observer in fact has many minds (in most versions, an uncountable infinity of them), and when the observer observes a system in a superposition (for example, $s + s'$) some of the minds observe the system to be in the state s, while others observe it to be in the states s', the proportions again matching the quantum-mechanical probabilities. In the case of the Many-minds interpretations, rather than a single actual world with many realms of reality, there is a single "person" with many minds. Other than that, there are many similarities between the two interpretations.

The notion of a measurement is supposed to play no fundamental role in these interpretations. A measurement of an observable O on a system merely reveals the preexisting value in "your" world that the system had for O. That is, if you witness the result k, then you are in a world in which the system already had the value k for O. Similar remarks hold for the Many-minds theories, *mutatis mutandis.*

Many-worlds interpretations face a number of interpretive difficulties. One is that any quantum state can be written as a superposition in many ways. In the terms stated earlier, $s + s'$ is equivalent to an infinity of other superpositions, $t + t'$, where s and s' are different from $t + t'$. So given that the quantum state of the universe is $V = s + s' = t + t'$, are the realms of reality (the "worlds") defined by the states *s* and *s′* or *t* and *t′*, or all of the above? If one of the former two, then the interpretation faces the obvious question why one (e.g., *s* and *s′*) rather than the other (e.g., *t* and *t′*). If the latter, then the interpretation faces the problem of how to define a probability measure over all of the components that can appear in any decomposition of the quantum state. Indeed, if such a measure is supposed to represent "ignorance" about which world one occupies (or which mind is "one's own") then it is far from clear that a satisfactory measure can be defined.

This issue is related to another severe problem facing these interpretations, namely, how to justify, or even to understand, the probabilities of standard quantum theory. The most obvious way to conceive of probabilities in these interpretations is as a measure of ignorance either about which world one occupies or about which mind is one's own. The problem is that it is not at all clear why that ignorance should be measure by the quantum-theoretic measure (except by stipulation).

But perhaps the most significant obstacle facing the Many-worlds and Many-minds interpretations is the sheer implausibility of the hypotheses. The central issue facing these interpretations is whether the difficulties we have understanding quantum theory really force us to such extreme measures.

See also PHYSICS, QUANTUM

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MATERIALISM

The term *materialism,* derived from the Latin word *materia* (timber, matter), was coined about 1670 by the British physicist Robert Boyle (1627–1691). Its French equivalent, *materialisme,* was used probably for the first time by Pierre Bayle (1647–1706), although it was not yet listed in his famous *Dictionnaire historique et critique* (1697). The German term *Materialismus* seems to have been introduced around 1700 by Gottfried Wilhelm Leibniz (1646–1716). Since then it has been employed to denote any theory that considers all events in the universe to be sufficiently accounted for by the existence and nature of matter.

Historians of philosophy often distinguish between different versions of such theories: *theoretical materialism,* the philosophical doctrine according to which, in contrast to idealism, matter is the only substratum of all existence and all mental or spiritual phenomena are merely functions of it; *psychological materialism,* which claims that the soul or spirit of living organisms consists only of matter or is a function of physical processes; *physiological materialism,* according to which mental activities can be explained as biological processes; and *dialectical materialism,* or its variant *historical materialism,* which regards all important historical events as result of the economic developments of the human society. Finally, the term *materialism* is also used in the disapprobatory sense of denoting excessive desire for material goods and wealth.

Ancient Greek materialism

Following Friedrich Albert Lange's influential *History of Materialism* (1865), which opens with the statement that "materialism is as old as philosophy, but not older" (p. 7) many historians identify the beginning of materialism with the birth of Greek philosophy in the sixth century B.C.E. They regard Thales of Miletus, who is generally credited with having been the founder of Greek science, mathematics, and philosophy, as the first proponent of materialism. They claim that his well-known statement "all things are water" implies that water is the only and universal substratum of which all other bodies are merely modifications. Although Thales's specific choice of water as the fundamental matter did not satisfy his successors, his distinction between appearance and a reality that becomes comprehensible through the unifying function of reason was of lasting consequence for philosophical thought. His disciple, Anaximander of Miletus, replaced water by the more abstract *apeiron,* some kind of infinite and indistinct eternal matter to which everything that exists owes its being.

Anaximander's disciple, Anaximenes, in turn called the fundamental cosmic matter "air" or "breath" claiming that air, when cooled, becomes vapor or mist, when rarified fire, and when condensed wind, cloud, water, earth, or stone. It should be noted, however, that at those early times matter and mind, or body and soul, were not sharply distinguished from one another so that the apparently purely material substratum included a spiritual ingredient. Some historians of philosophy prefer therefore to call these Ionian philosophers not materialists but *hylozoist.* The term *hylozoism,* derived from the Greek words for wood and life, means that there exists only matter, but this matter is animated, matter and life being inseparable.

A more authentic materialism is the *atomism* developed by Leucippus and elaborated by his disciple Democritus of Abdera who flourished about 400 B.C.E. They taught that there exist only empty space and atoms, which are indivisible, indestructible, and imperceptibly small particles of matter, differing in size and shape and moving in space. About a century later, Epicurus (341–270 B.C.E.) adopted the Democritian theory of atoms as a mechanistic explanation of all phenomena and used it as the basis of his philosophical system, which became known as *Epicureanism.* The most influential expositor of Democritian materialism and Epicurianism was the Roman philosopher and poet Lucretius of the first century B.C.E. In the six books of his poem *De Rerum Natura* (On the nature of things), he presented a materialistic explanation of mind, of soul, and of sensation, as well as of the phenomena of life, and thus taught the groundlessness of the fear of death and divine punishment since the event of death is merely the dispersion of the atoms.

Modern materialism

Due to the facts that the Christian Fathers, like Tertullian (c. 160–c. 240 C.E.), Arnobius (253–c. 327 C.E.), or Lactantius (c. 250–c. 325 C.E.), rejected philosophy as a heathen product, and that since the thirteenth century Aristotelianism, which rejected atomism, dominated Western thought until the age of the Renaissance, materialistic theories were virtually anathematized prior to the seventeenth century. Their revival is attributed mainly to the empiricist Pierre Gassendi (1592–1655), a Catholic priest with orthodox views in theology, but nevertheless a staunch opponent of Scholastic Aristotelianism, and to the political writer Thomas Hobbes (1588–1679), the son of a clergyman. Gassendi revived Epicurean atomism but made it compatible with Christian doctrine by asserting that atoms are not eternal but have been created by God. In his *Syntagma Philosophiae Epicuri,* published in 1658, Gassendi developed an atomistic theory that extends over physics and psychology without denying the existence of divine providence. Hobbes started with the notions of space and time, which he regarded as correlatives of the primary attributes of body, namely extension and motion. The resulting system turned out to be a rigorously deterministic materialism. Since all that really exists is, according to Hobbes, material and extended, the human soul cannot be immaterial; even thought must be some kind of an action of bodies. Furthermore, since human beings and the society of human beings are but groupings of bodies, the laws of human behavior and of human societies must obey the laws of motion as they are known in physics.

France. Gassendi's revival of Democritean atomism served as the foundation of what became known as the French materialism of the eighteenth century. Its main representatives are Julien Offray de la Mettrie (also called Lamettrie) (1709–1751), Claude-drien Helvétius (1715–1771), Denis Diderot (1713–1784), Paul Henri Thiry d'Holbach (1729–1789), and Pierre-Jean-Georges Cabanis (1757–1808).

Lamettrie came in contact with the Dutch philosopher and *iatromechanist* Hermann Boerhaave (1668–1738), who claimed that all organic processes can be explained by the laws of the physical sciences. Influenced by Boerhaave, Lamettrie published in 1745 his *Histoire Naturelle de l'Ame* (Natural History of the Soul), in which he presented his views concerning the nature of matter, its relation to form, and its capacity for motion and for sensation. Since matter becomes a definite substance through form, which it receives from another substance, form can only be known in its combination with matter. Matter itself is endowed not only with motion; it also possesses the capacity of sensation. In his *L'Homme machine* (1648), Lamettrie accepted René Descartes's (1596–1650) view that animals are merely machines and that all intellectual phenomena that they display must be mechanically explainable. But he went further than

Descartes when he argued that if an animal can feel and perceive without an immaterial soul due to its nervous and cerebral organization, there is no reason to assume that humans have spiritual souls. Since the laws of nature are the same for all that exists, plants, animals, and humans are subject to the same laws.

Lamettrie's books were publicly burned on account of their materialism and he had to flee to Berlin. Helvétius' work *De l'Esprite,* published in 1758, was also condemned by the Sorbonne as preaching a materialistic amorality and, like Lamettrie, Helvétius fled to Germany where he was received with high esteem. What Descartes was for Lamettrie, the French sensationalist Etienne Condillac (1715–1780) was for Helvétius. Following Condillac, according to whom all human faculties are reducible in essence to a sensory basis, Helvétius developed a materialistic philosophy on the fundamental assumption that all that people know they know only through the senses, and hence their ideas of deity, love, the soul, and so on, are merely modified forms of the objects that impress them in their daily material experience. Helvetius's materialism culminated with the conclusion that "enlightened self-interest is the criterion of morals."

Diderot, well known as the editor-in-chief of the French *Encyclopédie,* changed his views from an initial theism in which he was educated at a Jesuit school, through a period of deism, to an atheistic materialism. Diderot professed a biologically oriented materialism, since for him the entire universe is a perpetual circulation of life in which everything changes, evolution is a wholly mechanical process based on the laws of physics. In his *Pensées sur l'Interprétation de la Nature* (Thoughts on the Interpretation of Nature, 1754) he declared that the often pronounced view that body is in itself without action and without force is a monstrous error because "matter, but the nature of its essential qualities, whether it be considered in the smallest or largest quantities, is full of activity and force." The soul of the human being, who is part of nature, is not separate from body, and psychology is merely physiology of the nerves.

Holbach spent most of his life in Paris, where he wrote more than four hundred articles for the *Encyclopédie*. He is known chiefly as the author of the *Système de la Nature, ou des Lois du Monde Physique et du Monde Moral* (The System of nature, or the laws of the Moral and Physical world), published 1770. It has been called "the Bible of French materialism." It begins with the statement that although man imagines that there exists something beyond nature, all that exists is nature, and nature is nothing but matter and motion. Matter has always existed and has always been in motion. All particular things originate from matter by means of particular motions that are governed by unchangeable laws. Man, who is part of nature and as such a purely material being, only imagines that he has an immaterial soul. But all mental activity is in reality only some motion in the brain. Free activities or free will can not exist since all feelings, volitions, or thoughts are always subject to the eternal and unchanging laws of motion. Life is the sum of bodily motions and ceases when these come to an end. Holbach, more than any other materialist, stressed the point that materialism implies atheism. If there were a God, he argued, God would be located in nature, for there is nothing beyond nature; but if God were part of nature, God would be nothing but matter and motion. The idea of God, he concluded, is only a superstitious product of ignorance and desperation. Holbach even had no qualms to declare that the idea of God is the cause of all evil in society.

Cabanis, a friend of Holbach, was not always consistent in his philosophical writings, but judging from his principle work, *Rapports du Physique et du Moral de l'Homme* (On the Relation between the Physical and Moral aspects of man, 1802), he may be best characterized as having been a physiological, or even psychological, materialist. For, in his view, body and mind are not merely interacting with each other but are one and the same thing, and the human soul is matter endowed with feeling. The human being is simply a bundle of nerves, or as Cabanis phrased it, "Les nerfs—voilà tout l'homme!" (The nerves—that's all there is to man). Sensibility and thinking have their foundation in physical processes; when impressions reach the brain, they cause it to act and to "secrete" thoughts just like the liver secretes bile.

England. Cabanis and French materialism in general exerted a lasting influence on later philosophical movements, like that of the so-called *idealogues,* represented by Destutt de Tracy (1754–1836), or the *epiphenomenalists,* like Thomas Henry Huxley (1825–1895). On the other hand, retrospectively viewed, Cabanis's conceptions of materialism had much in common with the earlier formulation of materialism by Thomas Hobbes. Still, Hobbes was one of the earliest materialists in modern philosophy. As stated in his *De Corpore* (1655), philosophy means to think, and to think means to combine or separate thoughts; hence the objects of philosophy are composable and decomposable objects or bodies. Pure spirits or God cannot be thought. Since human beings and human society are but grouping of bodies it should be possible to deduce the laws of the behavior of human individuals and societies from the laws of bodies, that is, from the definitions of space, time, force, and power. Geometry describes the movements of bodies in space; physics the effects of bodies upon each other; ethics the movements of nervous systems; and politics the effects of nervous systems upon each other.

Hobbes, like most other English materialists, in contrast to their French counterparts, did not consider atheism to be a logical implication of materialism. In fact, most English materialists reconciled materialism with religious belief. John Toland (1670–1722), for example, professed in *Letters to Serena* (1704) and in *Pantheisticon* (1710) an extreme materialism that, in his view, does not conflict with deism. A typical example of an English materialist is also the physician David Hartley (1705–1757), the founder of the Associationalist School of psychologists. In *Observations on Man, his Frame, his Duty, and his Expectations* (1749) he reduced the whole of human thought and sensation to physical vibrations of the brain.

The most famous example of the compatibility of English materialism with religious faith is Joseph Priestley (1733–1804), known to chemists as the discoverer of oxygen. Although sympathizing with Hobbes and proclaiming the materiality of the soul, Priestley served as a Unitarian minister and believed in the existence of God and the immortality of the soul. As he emphasized in his *Disquisitions on Matter and Spirit* (1777), "there is nothing inconsistent with Christianity and the conception of the materiality of the human and divine soul."

Germany. In Germany a systematic philosophical materialism could gain ground only after the disintegration of the German idealism, which had culminated with Immanuel Kant (1724–1804) and collapsed with the death of George Wilhelm Friedrich Hegel in 1831. Kant, in his influential *Critique of Pure Reason* (1781), condemned materialism, just like spiritualism, as utterly useless (*untauglich*) for any explanation of reality. So did Johann Gottlieb Fichte (1762–1814), the philosopher of romantic idealism, and his disciple Friedrich Wilhelm von Schelling, according to whom "God affirms himself in Nature." The rise of German materialism in the post-Kantian period received its chief motivation from the achievements of science. The synthesis of urea from cyanic acid and ammonia by Friedrich Wöhler (1880–1882) and of fructose and glucose from their chemical elements by Emil Fischer (1852–1919) shattered the traditional belief that organic matter could only be formed by vital processes. Hermann Helmholtz's (1821–1894) discovery of the conservation of energy in organic and inorganic systems, combined with the atomic theory and Charles Darwin's theory of evolution, contributed decisively to the conception that life, mind, and consciousness are properties of energized matter. Thus, Jacob Moleschott (1822–1893) denied in his *Der Kreislauf des Lebens* (The Circularity of life, 1852) the existence of dead matter or of a matter-free force of life.

An extremely antireligious version of materialism was published in 1855 by Karl Vogt (1817–1895) in his *Kohlerglaube und Wissenschaft* (Implicit faith and science) as a sequel to his famous Göttingen controversy (1852) with the physiologist Rudolph Wagner (1805–1864), the so-called *Materialismusstreit* (Controversy about materialism), which raised wide public attention. Of greater influence, however, was Ludwig Buchner's (1824–1899) materialistic and atheistic book *Kraft und Stoff* (Force and matter) which, first published in 1855, appeared in more than twenty German editions and was translated into fifteen languages. A noteworthy example of the enormous influence that this book exerted, especially in Germany, is the fact that it prompted Albert Einstein (1879–1955) in his adolescence to abandon completely his erstwhile youthful religious enthusiasm.

Hegel's death marked the rise not only of this "vulgar materialism," so called because of its propagandist appeal to the broad masses, but also of the politically oriented dialectical materialism. The "left Hegelians," among them Karl Marx (1818–1883), opposed Hegelian idealism and reduced all its standards to human needs and human existence. Marx and his collaborator Friedrich Engels

(1820–1895) rejected the idealistic philosophy, which regards matter as dependent on mind or spirit, and developed instead a materialistic philosophy called dialectical materialism, according to which a materialistic reality is the substructure to all human social manifestations and institutions. Marx, in *Das Kapital* (1867), argued on the basis of a historico-sociological analysis of economics that what he called the "bourgeoisie" is no longer capable of coping with the changed conditions of production and must give room to the proletariat. It was mainly Engels who blended Marx's economical doctrine with philosophical materialism. According to Engels the philosophy of materialism is based on the three laws of dialectic: the law of contradiction, the turning of quantity into quality, and the negation of negation to specific logical and methodological problems. Engels's conception of dialectical materialism lies at the foundation of Vladimir Ilyich Lenin's (1870–1924) *Materialism and Empiro-Criticism* (1919), which is his only work on philosophical principles and became the canon of the official philosophy of former Soviet Russia and modern China.

The challenge of physics

The conceptual foundations and scientific background of all materialistic systems of the eighteenth and nineteenth centuries was the notion of matter as conceived by classical physics, that is, as Isaac Newton (1642–1727) described it, "matter formed in solid, massy, hard, impenetrable, moveable particles" and "mass" being its numerical measure. These particles, whether of atomic or macroscopic size, move through space according to the strict laws of mechanics. The development of modern physics in the first quarter of the twentieth century led to a radical modification, if not complete disintegration, of this classical framework, a process often characterized as the "dematerialization of matter." The traditional representation of atoms, for example, as minute billiard balls complying with the classical laws of motion proved incompatible with the principles of modern physics, which is based on the theory of relativity and quantum mechanics. Einstein's famous mass-energy relation, for example, symbolized by $E = mc^2$, and a simple consequence of the special theory of relativity, is often interpreted as expressing the convertibility of mass or matter into energy or inversely of energy into matter. Werner Heisenberg's (1901–1976) Uncertainty Principle, one of the axioms of quantum mechanics, whether interpreted as expressing the essential property of material particles never to have simultaneously a definite position and a definite velocity, or whether regarded as reflecting only a limitation on the measurement, as well as Louis de Broglie's (1892–1987) related principle of wave-particle duality, showed that the ontology of classical physics, on which those materialistic doctrines were grounded, can no longer be maintained. Quantum field theories, which have become the most important tools in understanding the microscopic world, suggest that matter is merely some arrangement of properties of space-time itself, all elementary particles being described as manifestations of quantum mechanical fields.

Modern physics thus presents a serious challenge to conventional materialism. Perhaps the most acceptable answer to this challenge has been given by the philosopher Herbert Feigl in his response to Norwood Russell Hanson's paper "The Dematerialization of Matter," published in 1962 in the periodical *Philosophy of Science*. "I grant," says Feigl, "the abstract, unvisualizable character of most physical concepts, classical or modern. But I insist that physics deals with happenings in space-time, and that associated with those happenings there are aspects of mass, charge and motion which leave at least *some* characteristics of old-fashioned matter unaltered" (p. 569).

See also NATURALISM; SCIENTISM

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MAX JAMMER

MATHEMATICS

The ancient Greeks, building upon earlier work by the Egyptians and Babylonians, transformed mathematics into an integral part of liberal education during the fourth century B.C.E. The academic disciplines (*mathemata*) of arithmetic and geometry were then sharply distinguished from the menial rules of practical calculation (*logistica*) necessary for the everyday work of artisans, tradesmen, and money changers. Arithmetic studies the properties of whole numbers such as divisibility and factorization by primes, while geometry studies properties of magnitudes such as congruence, similarity, and proportion. Both are concerned with aspects of measurement, understood in a broad sense, but arithmetic deals with discrete quantities (multitudes of a unit) while geometry considers continuous magnitudes (line segments, planar areas, and solids).

The notion of a ratio (*logos*)—the size of one thing relative to another—plays a major unifying role, yet many advances in both classical and modern mathematics have sprung from the inherent tension between the continuous and the discrete. The tension we may sense today between our flowing, or continuous, temporal existence and the discrete digital world of the modern computer reveals the distinction between these cooperating opposites and suggests the possibility of a powerful interaction.

Pythagorean and Platonic connections

Measurement is made by expressing a ratio of the thing to be measured to a second thing, usually to a standard unit that is more familiar—nowadays taken to be a meter, second, liter, or the like. In the fifth century B.C.E. the Pythagoreans made much of the fact, said to have been well known already in China, that ratios of small whole numbers in arithmetic are related to harmonious musical intervals. Thus, to speak in modern terms, the easily recognizable octave is produced by two pitches in the ratio 2:1, while the ratio 3:2 yields a musical fifth, and 5:4 determines a third. Our ability to sense the ratios between pitches in music and their identification with ratios between numbers may have helped inspire the Pythagorean dictum, “All is number.” By this is meant, presumably, that integers and their ratios (*logoi*) have the power to express underlying harmonies in nature that will be hidden from those ignorant of mathematics. Perhaps the most familiar modern (nineteenth-century) example of this power is the order induced in the periodic table by the assignment of an appropriate atomic number—an integer—to each basic chemical element.

Pythagoras (c. 560–c. 495 B.C.E.) is traditionally credited with putting together two Greek words to coin the word *philosophy* (“love of wisdom”) and with objectifying the notion of order by taking the Greek word for it, *cosmos,* and giving this name to the universe. Despite his mystical leanings, Pythagoras is sometimes seen as the founder of Western science because his followers continually promoted mathematics as a means of finding order and harmony in the natural world. The Pythagoreans used the connection between arithmetic and the science of music to develop a musical scale based upon *just intonation* (and they appreciated the difficulties that were finally ameliorated in the eighteenth century by well-tempering). They also noted the more obvious connection between geometry and astronomy. Stars are like points and the constellations are formed by line segments joining pairs of stars—so that problems in navigation may become problems in geometry.

Aspects of astronomy are thus naturally modeled by geometry, just as some properties of music are modeled by arithmetic. But these sciences deal with things in motion—the rotating celestial sphere, the vibrating strings of a lyre—whereas the mathematics of arithmetic and geometry deal with idealized static objects such as whole numbers and stationary line segments. A striking analogy is due to Archytas (fifth century B.C.E.), a latter-day Pythagorean: Arithmetic is to Music as Geometry is to Astronomy. Almost a thousand years later these four mathemata became collectively known as the *quadrivium,* a name given them by the Roman philosopher Boethius (c. 480–c. 524), although his practical countrymen prized logistica more highly. Eventually, the quadrivium became an integral part of the classical liberal arts in medieval European universities.

The word *ratio* has long been associated with measured study and hence with reason itself, while *logos,* the Greek word for ratio, has taken on a wide-ranging religious significance as well. The unit generates all numbers, whose *logoi,* according to the Pythagorean faith, have the power to measure (know) everything in the cosmos. Thus, for the Pythagoreans, the logos is a mathematical means of expressing cosmic harmony. The variety of basic roles that the logos plays in mathematics, science, philosophy, liberal education, and religion is suggested by the wide usage of such cognate terms as *logic* and *analogy,* and the host of academic words with the suffix *-logy*. Pythagoras seems to have been drawn toward a holistic view encompassing all these spheres, but their explosive growth would make this view ever more difficult to sustain.

Plato (c. 427–347 B.C.E.) became familiar with Pythagorean doctrines through Archytas and endorsed their emphasis upon mathematics and their insistence upon the same basic education for men and women. Plato thought that our power of direct apprehension of idealized mathematical forms like the circle might be refined to help us apprehend such things as truth, beauty, and goodness—Platonic forms whose properties, moreover, might also be studied by deductive reason. If, as Plato insisted, mathematics helps train the mind to rise from the apparent and ephemeral to the true and permanent, then its study should promote both science and religion. Indeed, when Jewish and early Christian thinkers began to view Platonic forms as ideas in the mind of God, an important link was established between Platonism and Judeo-Christian thought.

Plato even suggested that the immortality of the soul is intimated by geometry, especially when learned by the Socratic method, where it may appear that we are remembering—rather than learning anew—connections between geometric forms that we had somehow forgotten. To Plato this implies the existence of some earlier state of fuller communion with the forms. We must therefore (re)search in order to remember where we came from. In the midst of this perhaps fanciful argument, however, is Plato's admonition with which all modern scientists would agree, that in research we must look beyond mere sensory impressions. The laws governing the stars are fairer than the stars.

Plato comes close to espousing a religious motivation for scientific inquiry by taking the position, ardently embraced much later by Johannes Kepler (1571–1630), that the universe is, in some sense, an expression of the nature of its creator. Many researchers in mathematics and science, including some to whom Plato's views might appear naïve, have occasionally expressed a belief that they are, so to speak, reading the mind of God. "We cannot read [the great book of Nature]," wrote Galileo Galilei (1564–1642), "unless we have first learned the language and the characters in which it is written .... It is written in mathematical language."

Mathematics as a human endeavor

A quick excursion sketching the rise of seventeenth-century calculus may help to put a human face upon the making of mathematics. In the early

Middle Ages a slowly growing quantitative sense began to evolve, later bolstered by the convenience of working with numerals developed in India that would eventually be used in Indo-Arabic decimal fractions. The preservation, refinement, and advancement of Greek and Indian ideas during the rising tide of the Islamic movement led to the development of algebra—the very word for which comes from Arabic (*al-jabr*) and has somewhat the sense of "rearrangement." Mohammed ibn Musa al-Khwarizmi (c. 780–c. 850 C.E.) began his influential algebra book of the ninth century by praising God for bestowing upon man the power to discover the significance of numbers. The word *algorism* (later, and more commonly, *algorithm*) derives from the author's patronymic.

Calculus may be seen as a post-Renaissance blending of these developments with a new propensity to think in terms of the intuitive notions of variable, function, and limit, coupled with the development of analytic geometry, which unites large parts of algebra and geometry through the use of Cartesian coordinates. The joining together of such diverse ideas gave mathematics (and physical science) an astounding vitality in the seventeenth century. Isaac Newton (1642–1727) and Gottfried Wilhelm Leibniz (1646–1716) were the first to see the calculus as a unified whole that studies the interplay between functions and derivatives. This interplay casts light upon previously perplexing philosophical and scientific problems concerning the notions of instantaneous velocity and acceleration, gives new and efficient ways to find optimal solutions to many types of problems, and provides natural and effective methods for solving equations and for finding lengths of curves and sizes of areas and volumes. Newton used the calculus, together with his physical laws (axioms) of motion, to show how Kepler's observations about planetary motion follow from the law of gravity.

The scientific successes of "reason" inspired attempts to extend its methods beyond science. The philosophy of René Descartes (1596–1650), who developed analytic geometry, drew a clear distinction between reason and ecclesiastical authority. Descartes—and, later, both Newton and Leibniz—made serious, rational contributions to theology.

The early reaction to such efforts by Blaise Pascal (1623–1662), who had helped develop several nascent branches of mathematics (probability, projective geometry, and calculus), would be telling. Repelled by the idea of a god "of philosophers and scholars," Pascal abandoned everything for theology, returning to mathematics only once, in 1658, when he published some pretty results about the cycloid that calculus students still study. Pascal's writings exalting heart over mind ("Humble thyself, impotent reason!") would be seen to help inspire romanticism during a much later period, which left in its wake a great gap between the sciences and the humanities. Mathematics would find itself stretched ever more tenuously across this gap.

Ironically, the great mathematical advances of the so-called Age of Reason owe more to the imagination and intuition of mathematicians than to their logic and reason. The development of calculus was facilitated, as its developers were well aware, by a relaxation of the strictures of rigorous geometrical methods that proceed from precise definitions and clear first principles. Instead, mathematicians embraced loose numerical methods allowing unending decimal expansions and other *infinite sums*—thus going far beyond the finite arithmetic of the Greeks. This attitude led both to unprecedented progress in research and to occasional confusion and contradiction. The logical difficulties encountered were principally due to the suggestive, but slippery, notion of an *infinitesimal,* which was supposed to be a discrete entity that retained qualities of the continuous. Not until the precise formulation of the notion of a *limit* by Augustin-Louis Cauchy (1789–1857) and others were these difficulties decisively overcome.

In the meantime the shaky foundations of the calculus were exposed by the philosopher George Berkeley (1685–1753), an Anglican bishop, who published in 1734 a witty and acerbic essay called *The Analyst,* where he famously (and justly) ridiculed infinitesimals as "ghosts of departed quantities." His subtitle—*To an Infidel Mathematician*—reflects his purpose, to rebuke mathematicians of his day by showing that their discipline contains mysteries no less subtle than those of theology. Perhaps the best eighteenth-century advice to those who would learn the calculus was given by the French mathematician Jean le Rond d'Alembert (1717–1783): "Go forward, and faith will follow."

The search for coherence: Euclid's legacy

The *axiomatic method* consists in somehow intuiting basic accepted facts (axioms) about a discipline and logically deducing all else. Axiomatization of the real number system in order to derive rigorously the results of calculus—and thereby answer criticisms of Berkeley and others—did not occur until the late nineteenth century, when finally rational sense was made out of the huge mass of calculus-inspired research largely due to, but overly dependent upon, an unbridled trust in mathematical intuition. Pressure to provide such coherence to a discipline usually comes only when its elements have been basically established and it is time to synthesize a great web of connections into a consistent body of work.

The most celebrated example of such a synthesis is Euclid's *Elements,* which appeared in Alexandria around 300 B.C.E. Here, the towering edifice of geometry appears to be solidly built up by logic, unerringly applied to a small number of "self-evident" facts that we are willing to accept at the outset. The *Elements* is doubly valuable, however, because its study—with the help of a skilled tutor—will also impart the dual thinking techniques of analysis and synthesis that are indispensable in achieving rational coherence in any discipline. Analysis, as Plato used the term, refers to the testing of the truth of a proposition by deducing implications from it. If one of these implications is false, then the proposition must of course be false (*reductio ad absurdum*); otherwise, one hopes to deduce a consequence that is self-evidently true, and a synthetic proof is said to be obtained if the steps in this deduction can be reversed so as to obtain the given proposition as a logical consequence of self-evident truths.

The power of such analysis had been strikingly felt when the central tenet of the Pythagorean faith—the proposition that every ratio can be expressed as a ratio of whole numbers—was tested and proved false by *reductio ad absurdum*: If the proposition were true, then the ratio of the diagonal of a square to its side would be expressible as a ratio of integers. But this implies (to use modern terminology) that the square root of two is rational, which leads to contradiction, as first noted by the Pythagoreans about 430 B.C.E. Perhaps partly as a consequence of the limitations of arithmetic revealed by this shock, the Greeks came to look more favorably upon geometry, which Euclid attempted to put on a firm, rational foundation. It was not, however, until the nineteenth century that the foundations of mathematics were seen to require substantially more careful attention than Euclid had provided.

Archimedes (287–212 B.C.E.) effectively invented mathematical physics by giving an axiomatic development to hydrostatics, beginning by deriving from simple axioms the fundamental law of the lever. He then went on to discuss rigorously how to find centers of gravity of complicated solids, solving problems that are routinely handled today, but only by using calculus in a fairly sophisticated way. Mathematical physics came of age with Newton in the seventeenth century, and physicists today who seek an axiomatic basis for quantum mechanics follow in this tradition.

Western civilization has absorbed over a thousand editions of the *Elements,* whose influence is sometimes subtly felt. As noted by Bertrand Russell in *Wisdom of the West* (1959), a revealing moment in the Enlightenment occurred in 1776 when Benjamin Franklin spotted the phrase "sacred and undeniable" in the penultimate draft of the American Declaration of Independence and suggested that "self-evident" be substituted. A revolutionary list of moral and political rights of individuals was thus introduced to the world not with a religious invocation, but with an implicit salute to Euclid: "We hold these truths to be self-evident."

In contrast to Euclid, who presumably thought that his basic axioms about geometry were obviously true, both Nicolaus Copernicus (1473–1543) and Kepler on occasion spoke of an "axiom" of astronomy as a provisional truth that one might someday hope to establish. Axioms of empirical disciplines may alternatively be viewed simply as facts to be tested by analyzing their implications to see how well they model reality. The scope of axiomatics was decisively extended beyond the sciences when Baruch Spinoza (1632–1677) set down philosophical axioms and deduced the consequences in his *Ethics.* Systematic theology embraces a similar method of exposition when it exhibits the collective implications of basic religious tenets as a rationally coherent system.

In light of these modern points of view, the existence of non-Euclidean geometry—a startling development when Euclid was thought to represent "absolute truth"—is now seen as unsurprising. If "light rays" of physics are to be modeled by "lines" from geometry, why should the lines satisfy Euclid's axioms, now that we know of consistent mathematical structures developed by N.I. Lobachevsky (1792–1856) and G.F.B. Riemann (1826–1866) in which "points" and "lines" can be defined in such a way that Euclid's parallel postulate fails while the other axioms hold? Modern physicists routinely use non-Euclidean geometry to model the cosmos.

Faith in Euclid's absolute truth is thus clearly unfounded. In fact, modern mathematicians, when presented with axioms defining a vector space or some other mathematical structure, typically do not ask whether the axioms are "true," but instead set about deducing theorems that must hold for every structure satisfying the given axioms. The existence of foundational mathematical structures such as the real number system, out of which vastly complicated, useful, and interesting structures can be constructed, is generally regarded as unproblematic by working mathematicians. Mathematical logicians, on the other hand, study foundational questions intensely, usually basing their work upon the theory of sets. The surprising "incompleteness" theorem proved in 1931 by Kurt Gödel (1906–1978) demonstrated unforeseen limitations in the power of the axiomatic method and has sparked further study.

Conclusion

Modern mathematics has expanded far beyond the study of calculus and differential equations that has helped scientists to cope with continuous processes and, as well, beyond the developments in probability and statistics that have advanced the mathematical treatment of discrete processes. Carl Friedrich Gauss (1777–1855), perhaps the greatest modern mathematician, made deep contributions to almost all areas of the subject. By the early twentieth century, however, the scope of mathematics had grown so large that no single mathematician could claim to have mastered more than a small portion of the field.

The attraction of mathematics as a worthy human interest lies in discovering and establishing surprising and interesting connections between apparently disparate mathematical ideas that have not yet been fully comprehended. Mathematicians pursue useful goals, but while attaining them they often meet new ideas without immediate practical value that are appealing in their own right. Sometimes, intriguingly, these ideas prove to be surprisingly useful, whereas their initial appeal is only aesthetic in the sense that they seem to call for an imaginative synthesis expressed with clarity and style. "The love of a subject in itself and for itself, where it is not the sleepy pleasure of pacing a mental quarter-deck, is the love of style as manifested in that study," said the mathematician and philosopher Alfred North Whitehead (1861-1947).

Whitehead contended that pure mathematics, in its modern developments, may claim to be the most original creation of the human spirit. A similar claim might be made in connection with an often overlooked feature of its ancient development. Howard deLong perceptively observes in *A Profile of Mathematical Logic* (1970) that early Greek interest in abstract thought owes much to the expansion, from the physical to the mental arena, of the familiar spirit of competition and play. The sportive aspect of the play of the mind, which animates mathematics in its purest form, is bound up with this remarkable growth of the human spirit so long ago.

In *A Mathematician's Apology* (1940), G. H. Hardy (1877-1947) bases his defense upon aesthetic grounds and confesses a genuine passion for his calling. Something akin to Hardy's passion is known to all who have experienced the revelation that follows a spell of total concentration and have found themselves echoing in their own tongue Archimedes's famous cry of eureka ("I have found it"). Mathematicians count heavily upon the spirit that compels such engagements and articulates such an involuntary cry of delight. What transpires under its spell may even seem like something done to—rather than by—a mathematician. No one seems ever to have argued, however, that a calling to an Archimedean engagement implies the existence of a "caller." Attitudes of mathematicians toward religion range from Whitehead's well-known sympathy for the religious experience to Hardy's strongly opposing view.

See also ALGORITHM; GALILEO GALILEI; PLATO

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W. M. PRIESTLEY

MEDICAL ETHICS

Moral concerns have always been implicit in medicine. Indeed, the division between science and values—the objectivity sought in the study of nature and the values governing human behavior—disappears at the bedside. The medical choices made by physicians and their patients must, by their very nature, reflect a complex array of values that determine how the findings of clinical science and the applications of their associated technologies are to be deployed in the care of the ill. Thus medicine necessarily obscures the line separating science and human values because of the intimate connection between clinical science and its object of study and intervention: the person—the nexus of politico-judicial action, moral agency, scientific scrutiny, and religious sanctification.

The origins of contemporary medical ethics may be traced to the Enlightenment, when the science of morals and the morals of science became the subject of intense deliberation, and from which medical ethics arose as a system of mutually related contracts between doctor and patient (Haakonssen 1997). But an even older religious tradition—Catholic (Kelly 1979), Protestant (Fletcher 1954), and Jewish (Jakobovits 1959)—has debated the moral implications of modern medicine generally, and in particular, since the mid-twentieth century, those matters arising in consequence of clinical interventions that challenged dogma about life and death, including abortion, terminal care, genetic counseling, and the like. But medical ethics in its present form—philosophical, secular, legalistic, and professionalized—has had a brief history.

During the late 1960s, medical ethics burst forth into the political arena. Rapid technological advances brought new challenges to the very definition of life and death. This in itself would have initiated speculations over how such new-found scientific power should be utilized. In addition, a massive social realignment was underway under the auspices of a renewed commitment to civil and human rights. Focused upon various forms of paternalism, particularly heated debates about informed consent for therapy, protection of subjects enrolled in human research, and recourse to medical malpractice, stimulated both a reexamination of the ethics underlying these issues as well as a more general discussion of medicine's moral philosophy and legal standing (Rothman 1991; Jonsen 1995). Soon, medical ethics became a formal discipline, replete with institutes, journals, books, conferences, and professionals devoted to what had heretofore been a subject reserved for religious contemplation.

Definitions and distinctions

Medical ethics may be defined as the discourse that seeks to define moral guidelines for the care of patients. Within this discipline, a distinction must be drawn between *judicial medical ethics* and *philosophical medical ethics*. In the former, medical ethics comprises rules or procedures established by governing agencies and the courts meant to guide decision-making in difficult areas like abortion, for example, or the involuntary commitment of a psychotic patient. In this context, medical ethics implicitly informs the legal directives, and "risk management," the distillation of this discourse, defines the procedures hospitals and health care professionals follow to minimize their legal liability. On the other hand, philosophical medical ethics has no proscribed rules, only a tradition of offering philosophical or theological perspectives to ethical dilemmas and proposing possible answers. Thus, diverse matters ranging from informed consent to end of life issues to new technological opportunities (e.g., artificial insemination) may be addressed at these two levels, the judicial and the philosophical: What, on the basis of the law, is the correct procedure for dealing with a clinical predicament? or, alternatively, What are the secular ethical or religious principles that offer ways of thinking about a morally ambiguous problem? Judicial medical ethics—practical instructions, rules, regulations, contracts, and ultimately the law—may be distilled from such philosophical deliberations, and these, together with judicial precedent and political considerations ultimately result in accepted practice. In short, although the law is the final arbiter of practice, philosophical ideas impact on the shape of social policy.

This entry will consider "medical ethics" solely in its philosophical mode. It is around this topic that one can most clearly discern how theologians, poised and ready to participate in a discourse they had already developed for their own purposes, offer insights (and ideologies) from their rich intellectual and religious heritage in order to influence the development of contemporary judicial and philosophical medical ethics (Lammers and Verhay 1987; Verhay and Lammers 1993; Camenisch 1994).

The competition of moral principles

Medicine reflects broad social values, and American multiculturalism has demanded a mixture of ethical precepts from diverse sources. In the end, citizens live together under a common law, one that seeks to satisfy the pluralistic demands of contemporary life and still remain faithful to the older core of foundational principles. Since at least World War II, America has developed a rights-based culture that endeavors to respect the autonomy of its citizens and thereby to enhance their ability to enjoy life's pursuits offered by the opportunities afforded by civil equality and respect for differences in religion, race, sexual orientation, and a whole host of differentiating characteristics (Sandel 1995). American medicine has been caught in this vast social experiment stimulated by cultural diversity and unified by constitutional law.

So when medical ethicists ponder, "Under what circumstances are particular ethical responses evoked?" or "What are the ethical implications of those ethical choices?" their answers draw upon a complex array of moral principles forged together from various religious traditions and secular moral philosophies. Given the current dominant legal and political culture based upon the protection of individual rights, autonomy as a governing philosophical principle has been prioritized in medical ethics. For, as noted above, in the process of deliberating medical ethics, philosophers consider the practical application of their studies, and these are, in a sense, over-determined by legal interpretation, one focused on rights. Thus, in the judicial context, medical ethics is like a lopsided table with five legs: Although autonomy, beneficence, justice, utilitarianism, and non-malfeasance each claim consideration, autonomy usually trumps other contenders (Beauchamp and Childress 2001). This dominance has been widely regarded as both a judicial and philosophical problem.

Autonomy draws on two understandings of freedom (Berlin 1969): One is negative, the freedom from oppression or interference by another, and the second is positive, the freedom to participate in the process by which one's life is controlled. In the research setting, autonomy in the form of informed consent is the governing principle that protects human research subjects from hidden manipulation (Belmont Report 1979). And while in the clinic and the hospital, similar rules of informed consent operate, a rights-based morality makes little attempt to articulate the ethics of other dimensions of the doctor-patient relationship. And here we discover an ambiguous moral construction lying at the foundation of medical care.

Indisputably, autonomy serves a vital judicial-legal function in our system of medical law, and this may well account for its continued importance, but it is more likely that the moral depth of our notions of respect for persons reflects a still deeper commitment to Western religious roots (Downie and Telfer 1969; Thomasma 1984; Engelhardt 1996). Our care of the ill is based on a deep metaphysical sense of response to the other, a reaction that generates *response-ibility* (Tauber 1999). This ethical metaphysics is essentially a theological assertion, not a philosophical one. This position was first espoused by the early founders of American medical ethics, Joseph Fletcher (1954) and Paul Ramsey (1970). They championed autonomy, because this principle reflected their basic humanitarianism as theologians (Jonsen 1998). But autonomy had little philosophical support in their writings, where it served as a placeholder for a humane medicine, one that held the sanctity of life paramount. Indeed, by not delineating how autonomy was in competition with other moral tenets, these early discussions inadvertently obfuscated the complexity of medicine's moral universe.

Physicians and nurses assume responsibility for the care of their patients, and the "moral space" in which patients reside is not necessarily coincident with that of autonomous citizens. Autonomy is inadequate, by itself, to account for medicine's moral calling because of two failings. First, from the patient's perspective, the notion of autonomy is frequently distorted in the clinical setting (Schneider 1998; Tauber 2001). Patients necessarily relinquish their full autonomy to experts, and in this regard, they cannot make truly autonomous, self-reliant, fully informed decisions, and must instead ultimately rely on the competence and good will of their health-care providers to represent their best interests. Second, autonomy as a construct cannot account for the ethical responsibilities of the caregiver (Tauber 1999). The sense of responsibility exhibited by physicians and nurses arises from their sense of care for others, not primarily from a set of rules designed to protect patient autonomy. Respect for the person in this setting is implicit to their professional role, a role characterized by a profound sense of commitment to their charge. This ethic of compassion regards autonomy as only one of a number of moral principles governing the caring relationship, among which it finds in beneficence a more resonant expression of medicine's fundamental ethos. This is the moral principle that perhaps most obviously captures the Judeo-Christian religious ethos, the appreciation that God's work on Earth is articulated through the caring relationship between people and their respective responsibility for each other (Pelligrino and Thomasma 1988; Kultgen 1995). The foundations of social justice and much of the implicit understanding of our social mores are based on this deep moral maxim.

Thus "patients" and "citizens" are revealed as not necessarily occupying the same ethical domain. While their respective moral identities overlap, they nonetheless are distinct. The patient, at least in the autonomy model, receives medical attention only to the extent that his or her rights as an autonomous citizen are respected. This is essentially a defensive posture, one at potential odds with those moral (ultimately religious) concerns most prominent for the doctor or nurse, whose primary ethical affiliation is to beneficence (Pelligrino and Thomasma 1988) or, in another format, responsibility (Tauber 1999).

Seeking a synthesis

Much of philosophical medical ethics has been devoted to balancing the politico-legal view of individual autonomy with other moral principles that make strong claims in the medical culture. Although (secular) autonomy and (religious) beneficence has each followed a historical and philosophical trajectory of its own, they may be reduced to a more basic formulation, a moral foundation, which, for the sake of simplicity is, "Respect for the person" (Ramsey 1970). This idea of the inalienable sanctity and dignity of every human being derives most directly from ancient themes in the Western religious culture rather than from philosophy as such, and may account for the hold of "autonomy" on Western moral sensibilities. For theologians as well as nonbelievers, the sanctity of life—essentially a religious principle—remains paramount even as it was secularized into the political principle of autonomy (Callahan 1969; Jonsen 1998).

Autonomy, a relatively new moral tenet, claims a dual heritage: The first source derives from notions of Puritan personal religious responsibility and conscience, balanced against the obligations of persons to a community designed to serve God (Shain 1995); the second source, again religious in origin, arises from natural law's endowment of persons with natural rights, self-governance, and the freedom to pursue their own dictates (Schneewind 1998). This latter tributary, one we might call individualistic, grew at the expense of communal values in the development of American democracy, while European views of autonomy have more evenly balanced community interests and responsibilities (as evidenced by universal socialized health care) against autonomy-based rights in health care delivery. Consequently, in the United States, individual rights increasingly have been regarded as sacrosanct, and correspondingly the respect for persons has shifted from one centered on communal responsibility—both the citizen's identification with the state and the state's responsibility for the citizen—to one focused on autonomy in its more atomistic interpretation (Sandel 1996). And here we see how an ethos of responsibility for others ("caring") may be subordinated to a preoccupation with protecting the rights of the individual.

The seam that ties religious and secular philosophies together is not always evident, which is strong testament to the success of liberal society, but as this discussion has emphasized, conflicting moral orientations may still show signs of differing ethical perspectives straining against one another. While autonomy carries the ancient banner of life's sanctity, its contemporary secularized meaning and applications have shorn off its religious heritage, leaving its more immediate allegiances plainly in view. So when this political and judicial principle is extended to medical ethics, the law accompanies the ill to the clinic and hospital to protect citizens. Due to this legal extrapolation, the more ancient basis of the doctor-patient relationship must accommodate a superimposed orientation different in kind and purpose to an older ethic of caring. And perhaps of more concern, telling lapses in judiciary medical ethics appear as the discourse stutters when addressing the legal basis of beneficent concerns: Physician fiduciary responsibility, those duties dictated by law that translate beneficence into standards of care, are restricted only to maintaining patient confidentiality, disclosing financial conflicts of interest, and prohibiting the abandonment of patients (Rodwin 1995); Good Samaritan laws protect doctors from suits arising from non-consented care only in the most dire of circumstances; empathy has no legal basis whatsoever.

In summary, the complexity of medical ethics begs for a full hearing, to reflect both the claims of individual rights as well as the demands of a morality that fosters responsibility. In that discussion, a combination of various moral principles allows for a philosophical discourse that attempts to represent fairly diverse interests and relationships, including the challenge of accommodating different belief systems. The product of that deliberation, which must draw upon the entire Western tradition of philosophy and its handmaiden, theology, frames a perspective on, and the terms of, the never-ending debate over the most crucial nexus of human endeavor, the life and death decisions so manifest within modern medicine's power to influence, if not control.

See also ABORTION; BIOTECHNOLOGY; MEDICINE; REPRODUCTIVE TECHNOLOGY

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ALFRED I. TAUBER

MEDICINE

Religion and medicine are twin traditions of healing. Although they have overlapped for most of their history, in the past three hundred years the two traditions have become separate and have often been in competition with one another. At the close of the twentieth century, serious consideration began to be given to reintegrating religion and medicine. In this discussion, a review of the historical connection between these two traditions will be offered. Research that has led to a possible rapprochement will be examined as will the implications for practicing clinicians.

Historical background

There is a long historical tradition that connects religion and medicine. The first hospitals in western civilization for care of the sick in the general population, particularly for those unable to pay for their own care, were built by religious groups. In the fourth century, Basil, the Bishop of Caesarea established one of the earliest hospitals based upon the good Samaritan story in the Bible. This building was resurrected in present-day Turkey among almshouses and leper colonies. For the next thousand years, the church would build and staff most hospitals throughout the western world. Many early physicians, especially those in Europe during the Middle Ages and in the New England colonies of the United States during the seventeenth and eighteenth centuries, were also members of the clergy. In Europe, licenses to practice medicine were in fact controlled by the church and church-sponsored universities.

Similarly, the profession of nursing was to emerge out of the Christian church in the 1600s and 1700s with the Daughters of Charity of St. Vincent de Paul, an order of Catholic sisters devoted to the care of the sick. The Daughters of Charity also established the first nursing profession in the United States in Emmitsville, Maryland, in the early 1800s, modeled after nursing in France. Florence Nightingale (1788–1849), after receiving a "calling" from God, would later receive nurses training from the Daughters of Charity and the Protestant deaconesses (started up by Lutherans in Germany). After the Crimean War, Nightingale applied what she learned to a secular setting. Interestingly, though, up until the early 1900s, most hospitals in Europe and the United States continued to be staffed by nurses who were primarily from religious orders.

Beginning in the fifteenth century, the profession of medicine began to split away from the church, and the state took over the role of administering licenses to practice medicine. That separation would continue to widen until the early 1800s when it was nearly complete. For the last two hundred years, religion and medicine have been divided into separate healing disciplines, with very little overlap and very little communication between the two. However, since about the mid-1990s, especially in the United States, there has been active dialogue about bringing religion and medicine together once again. This movement has been highly controversial and has met with considerable resistance. A growing volume of research showing a connection between religion and health, however, has been breaking down the resistance.

Although the history reviewed above applies primarily to the Christian church, there has been similar interest in health and healing running through nearly all the major world religious traditions, including Judaism, Hinduism, Buddhism, Islam, and Chinese religions. Space does not allow for an adequate discussion of historical connections with medicine for each of these traditions, although resources that do so include Lawrence Sullivan's *Healing and Restoring: Health and Medicine in the World's Religious Traditions* (1989) and *Caring and Curing: Health and Medicine in the Western Religious Traditions* (1998) by Ronald Numbers and Darrel Amundsen.

Research on religion and health

The recent trend towards integration of religion and medicine has been stirred primarily by medical research demonstrating intimate and often complex relationships between religion and health. First, many patients indicate that religious beliefs and practices help them to cope with the stress of medical illness. In some areas of the United States, nearly ninety percent of hospitalized patients report that they use religious beliefs to at least a moderate degree to help them to cope. Nearly fifty percent of this group indicate that religion is the most important factor that enables them to cope with medical conditions and the stress they cause. Over one hundred studies have now documented the high prevalence of religious coping among persons with a variety of diseases ranging from diabetes, kidney disease, heart disease, cancer, arthritis, and cystic fibrosis, to more general conditions such as chronic pain.

There is also research demonstrating that persons who are religious end up coping better with physical health problems and disabling conditions. Of nearly one hundred studies conducted during the twentieth century on the relationship between religion and emotional well-being (happiness, life satisfaction, optimism, and hope), nearly eighty percent find that the religious person experiences significantly greater well-being. This is particularly true when populations of medically ill subjects have been studied. The religious are less likely to become depressed or anxious, and if they do develop these mental conditions, they recover more quickly. Suicide is less common among the more religious, as is marital dissatisfaction and divorce, and alcohol and drug use. Nearly 850 studies have now examined these associations, with between two-thirds and three-quarters of these finding that the religious person tends to be healthier and better able to cope with illness.

Of course, a number of studies also report that religion can be associated with worse mental health, more depression, and greater anxiety. This is particularly true for practitioners of religions that are repressive, controlling, and do not emphasize caring for self and others in a responsible way. Religion can be used to justify hatred, aggression, prejudice, and social exclusion. It may induce excessive guilt in situations where guilt is not healthy. Religion may also be used to replace professional psychiatric care for serious mental or emotional problems that require medication and biological therapies. In all of these ways, religion may do a disservice to mental health. In most cases, however, the emotional benefits of religious faith tend to outweigh the negative effects.

There is also a growing volume of research suggesting that religious belief and practices are related to healthier lifestyles, better overall physical health, and longer survival. Studies demonstrate stronger immune functioning among religious persons who are older, who are HIV positive or have AIDS, or have breast cancer. Death rates from coronary artery disease are lower among the more religious, even when health behaviors, diet, and social factors are taken into account. The same applies to mortality from all causes. Since 1990, over a dozen careful studies have demonstrated that the religious person lives longer than the person who is less religiously involved. In these studies, religion is measured by frequency of church attendance, private prayer and scripture study, meditation, and religious coping. Studies have not demonstrated that the broader aspect of religion called *spirituality* is associated with greater longevity. Spirituality is a broad concept, making it difficult to measure, whereas religious beliefs, practices, and commitment can be more easily assessed and quantified.

Why does religious belief and practice correlate with and predict greater physical health? The answer may lie in the mind-body relationship. There is growing evidence suggesting that emotions influence physiological processes. Psychological stress, anxiety, and depression have been related to impairments in immune functioning, delayed wound healing, and increased risk for cardiovascular morbidity. If religious beliefs and practices reduce emotional stress, counter anxiety, and prevent or facilitate recovery from depression, then religion may help to neutralize the health-impairing effects that these negative emotions have on physical health, and do so through known biological pathways. Mainstream scientists in the field of psychoneuroimmunology are beginning to explore these connections more seriously.

Since about 1980, people have become increasingly disillusioned with medical care that relies solely on high technology and focuses on the biology of disease, while neglecting the care of the whole person. That disillusionment has caused many patients to express a desire to have their spiritual and emotional needs met, as well as their physical needs. Between one-third and two-thirds of patients consistently indicate that they wish their physicians to address religious or spiritual needs in addition to medical needs, particularly when they experience serious medical problems or terminal illness.

Furthermore, there is research indicating that religious and spiritual beliefs impact medical decision making and may even affect compliance with medical treatment, making it essential for physicians to know about these beliefs. Some patients may use religion instead of traditional medical care to treat their illnesses. For example, they may decide to pray for their illnesses and stop taking their medications. There is also research showing that certain types of negative religious beliefs may adversely affect physical health and recovery from medical illness. Patients who feel punished or deserted by God, who question God's power and love, or who feel abandoned by their spiritual community, experience greater mortality and worse mental health outcomes.

Application to medical practice

The growing body of research on religion and health suggests at least the following four applications to medical practice in the West. First, in light of this research, some have argued that physicians should consider taking a spiritual history on patients with serious, terminal, or chronic medical illness. In the United States, only about one in ten physicians consistently addresses spiritual issues by taking a religious history, despite suggestions by a consensus panel of the American College of Physicians and American Society of Internal Medicine that such a history can be obtained by asking a few simple questions. Such questions include the following:

(1) Are religious beliefs a sense of comfort or a source of stress for the patient?

(2) Is the patient a member of a spiritual community and is this a source of support for the patient?

(3) Does the patient have any religious belief that may influence medical decisions or conflict with medical care?

(4) There any religious or spiritual needs present that need addressing?

Taking a spiritual history should be done in addition to (not instead of) competently and completely addressing the medical issues for which the patient seeks help from the physician. Thus, a spiritual history is most appropriate when there is more time in the schedule, such as during a new patient evaluation or during a hospital admission workup.

Second, if spiritual needs are identified when the spiritual history is taken, then the research suggests that addressing those needs should improve the health and coping capacity of the patient. This can be done in a couple of ways. The patient can be referred to a trained clergyperson or chaplain. Chaplains in the United States are required to undergo extensive training that prepares them to address such issues in the medical setting. Before a chaplain is certified in the Association of Professional Chaplains, he or she must complete four years of college, three years of divinity school, one to four years of clinical pastoral education, and must take written and oral examinations. Thus, chaplains are skilled professionals with much to offer in this area. Sometimes, however, patients do not wish to speak with a chaplain or clergyperson. In that case, if the patient already has a trusting relationship with the physician, then the physician may need to be prepared to address such issues, even if this involves only listening and showing respect and concern. Nearly two-thirds of the medical schools in the United States have elective or required courses on religion, spirituality, and medicine. In these courses, medical students are trained to take a spiritual history and to address spiritual issues in a sensitive and appropriate manner.

Third, in addition to taking a spiritual history and, if necessary, addressing spiritual issues, the physician may choose to support healthy religious beliefs or practices that the patient finds helpful in coping with illness. Physicians should not prescribe religion for patients who are not interested in religion. There may be benefits, however, in physicians learning about the religious beliefs and practices of their patients and supporting those beliefs that the patient finds helpful and that do not conflict with medical care. Even when religious beliefs conflict with medical care, the patient is likely to profit when the physician tries to understand those beliefs and keep open lines of communication about religious issues with the patient. By way of supporting religious practice, some physicians have decided to pray with their patients. This activity is highly controversial in the medical setting. Conditions for its appropriateness include that:

(1) A spiritual history has been taken and the physician knows about the religious background of the patient.

(2) Religion is important to the patient and is used in coping.

(3) The religious background of the patient and the physician are similar.

(4) Either the patient asks the physician to pray (i.e., patient initiates the prayer) or, if the physician initiates it, the physician is certain that the patient would appreciate this activity.

(5) The situation calls for prayer (i.e., a difficult, uncontrollable, or stressful situation, severe medical condition, or terminal illness).

Under such circumstances, it may be helpful for a physician and patient to engage in prayer together, enhancing the doctor-patient relationship by increasing trust.

Finally, the research suggests that new social arrangements for medical care may prove beneficial. For example, physicians might develop a communication network with local clergy, both to facilitate a referral base and to allow physicians to assess the community resources that are available to the patient. Religious communities often already provide volunteers to assist with homemaker services, rides to the doctor, respite for exhausted family members caring for the patient, and emotional support to the patient and the patient's family. Religious communities may also monitor the patient to ensure that the medical regimen is being followed and that medical problems are detected early and treatment is obtained promptly. Such a system works especially well when volunteers are appropriately trained and coordinated by a parish or congregational nurse—a registered nurse who is a member of and works professionally as a nurse within the congregation. A parish nurse can coordinate health programs within the congregation that involve screening for high blood pressure, diabetes, depression, and other diseases. A parish nurse can also provide spiritual care, communicate with physicians and nurses within the formal healthcare setting about the health condition of members of the congregation, train and mobilize volunteers within the religious community to meet the needs of sick members, and provide health education to keep healthy members well.

Religion and Western medicine are indeed coming closer and closer together. The research suggests that this is a positive trend—good for the health of patients and for the maintenance of the health of the community. It is also arguably good for the profession of medicine in the West, which is truest to its most basic aims when its practices support the health of the patients in every dimension.

See also MIND-BODY THEORIES; PLACEBO EFFECT; SPIRITUALITY AND HEALTH; SPIRITUALITY AND FAITH HEALING

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MEDITATION

Meditation, from the Latin word *meditari* (to meditate), means deep or continued reflection and is often seen as preparatory to contemplation, a state of direct spiritual or intuitive seeing. Meditation is found in all religious traditions but varies as to method, focus, and religious objectives. Practices range from the *apophatic,* an emptying procedure to clear consciousness (*via negativa*), to the *cataphatic,* where a specific image, idea, or deity is kept in mental focus (*via positiva*). Apophatic practices tend to be more cognitive and intellectual (mind), whereas cataphatic practices are more emotional and devotional (heart). Meditation is the focus of scientific research to determine the neurophysiological conditions productive of meditative awareness.

See also PRAYER AND MEDITATION; SPIRITUALITY

ERNEST SIMMONS

MEMES

The term *meme* was coined by British biologist Richard Dawkins in his 1976 book *The Selfish Gene* to describe a "unit of culture" (p. 203). Examples given are "tunes, ideas, catch-phrases and … the idea of God." These entities might, he said, act independently as "replicators," like genes, thus determining the state of culture entirely by natural selection among themselves. Critics point out that, if taken seriously, this is a highly reductive and fatalistic doctrine, claiming that memes, rather than human beings, control cultural development. But the suggestion is obscure. Many would argue that elements of culture are not independent entities, nor are units the same as replicators.

See also GENETICS; SOCIOBIOLOGY

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MARY MIDGLEY

MENDEL, GREGOR

Although some leading scientists in the late nineteenth century considered religion to be an impediment to progress in science, the life of the monk Gregor Mendel serves as an important counter-example. The fact that a monk initiated one of the greatest advances in biology demonstrates the poverty of the notion of there being a perpetual war between science and religion. In Mendel's case, rather than hindering science, religious institutions promoted scientific knowledge, experimentation, and progress.

Early life and influences

On July 22, 1822, Mendel was born in the village of Heinzendorf (now Hyncice) in northern Moravia (in the present-day Czech Republic), a part of the Austrian Empire that was culturally German. Mendel was originally named Johann, but took the name Gregor in 1843 upon entering the Augustinian order of the Roman Catholic Church. His father was a peasant farmer with a keen interest in improving agriculture. A priest in his community, Father Schreiber, used his knowledge of fruit trees to help his parishioners practically. He studied the latest techniques for improving fruit yields, practiced artificial fertilization, and distributed grafts to community members, including the Mendel family.

Mendel's intellectual abilities were recognized early in his life, and his family sent him to school first in Leipnik (Lipnik) and then to Gymnasium in Troppau (Opava). After graduating from Gymnasium, he attended a two-year course of study at the Philosophical Institute in Olmütz (Olomouc), which was interrupted for a year due to illness. He graduated from the Philosophical Institute in 1843, having studied religion, philosophy, ethics, mathematics, and physics, in order to prepare for further studies in natural science at a university. While in Olmütz, Mendel had grave financial difficulties because his father was incapacitated from work as a result of an injury, and Mendel had difficulty finding tutoring jobs. His poverty probably brought on his illness and caused him continual travail.

Upon the recommendation of one of his teachers, Mendel entered the Augustinian monastery in Brno in 1843. He had begun contemplating entering the Catholic priesthood about three years earlier, but it is not known how seriously or deeply he felt a religious calling. Mendel's own account of entering the monastery emphasized his need to escape from poverty rather than an inner religious motivation. Mendel also knew that the monastery in Brno would be a hospitable environment for pursuing studies in the natural sciences.

Indeed, the Brno monastery, under the leadership of Abbott F. C. Napp, attracted a number of talented men interested in science. Napp himself studied horticulture and wrote a manual about improving plant varieties. He set up a nursery in the monastery where new plant varieties could be developed. Thus, the monastery provided a very propitious environment for the young Mendel, who was encouraged to teach science in nearby schools. The monastery also allowed him to attend the University of Vienna from 1851 to 1853 to study natural science so he could pass the exam to qualify him to teach in a Gymnasium. Mendel never passed this exam, however.

Although the monastery was a stimulating place for the study of natural science, the religious training and exercise in the Brno monastery seems to have been perfunctory. The bishop of Brno criticized Napp and the monastery for devoting so much attention to science, while neglecting the spiritual dimension of monastic life. Shortly after Mendel arrived, a monk there was stripped of his authority to teach because he was accused of introducing Hegelian and pantheistic doctrines into his scientific writings. Napp tried to defend this monk, but to no avail. Mendel never challenged the Catholic Church or its teachings, but his energies were clearly devoted more to scientific pursuits than to religious ones.

Experiments with peas

From 1854 to 1863 Mendel carried out his pea experiments, which later became famous for laying the groundwork for the modern science of genetics. Because Mendel relied on statistics to analyze the results of his work, his background in physics and mathematics provided him insight in developing these experiments. To perform his experiments, Mendel selected twenty-two varieties of pea plants that bred true (i.e., each was a pure variety that, when crossed with its own variety, always had offspring with the same traits as the parents). Each variety was crossed with another with which it differed in an obvious way, such as seed color, pod shape, position of flowers, or length of stem. For example, he crossed one pea variety that had round seeds with another variety that had angular seeds. In the first generation hybrids Mendel observed that all the offspring had the trait of only one of the parent varieties. The hybrid, between peas with round seeds and those with angular seeds produced all round seeds in the first generation. Mendel called the trait that appeared in the first generation the *dominant* trait. This demonstrated that hereditary characters did not blend, as many scientists of the time supposed they did, but rather they were discrete factors.

Mendel continued his experiment by self-fertilizing the first generation hybrids. He discovered that both original traits reemerged in a ratio approximating three (for the dominant trait) to one (for the recessive trait). In the case of the round and angular seeds, Mendel's actual data showed 5474 round seeds and 1850 angular seeds in the second generation. Mendel concluded from his experiments that each plant had two hereditary characters. Each parent would pass only one of its characters on to its offspring. These characters segregate randomly, leading to the ratios Mendel found. This explanation is known as *Mendel's Law of Independent Assortment.*

Mendel published the results of his pea experiments in 1866 in the *Proceedings of the Natural Science Society* of Brno, but even though some botanists cited his work subsequently, none recognized the full significance of his experiments before 1900. Mendel even corresponded with Karl Nägeli (1817–1891), a prominent botanist, but despite his interest in Mendel's work, Nägeli never realized how important it was. When Mendel died on January 6, 1884, he was almost unknown, though he did express confidence late in his life that his work would be recognized in the future.

Historians still debate the significance of biological evolution for Mendel's work. Charles Darwin (1809–1882) had not yet published his theory of evolution when Mendel began his experiments, but Mendel was already conversant with Charles Lyell's (1797–1875) uniformitarian geology, which had been a formative influence on Darwin. Mendel also studied botany at the University of Vienna under Franz Unger (1800–1870), who embraced a pre-Darwinian evolutionary theory. Mendel was thus fully aware of debates about biological variation and speciation, and he may have hoped that his hybridization experiments would shed light on the evolutionary process.

The rediscovery of Mendel's work in 1900 by three different scientists—Hugo de Vries, Carl Correns, and Erich von Tschermak—occurred in the context of debates over evolution. Biological evolution was widely accepted by European scientists by 1900, but scientists did not have a satisfactory explanation as to how variation occurs or what the mechanisms of heredity are. Mendelian genetics provided new insights about heredity, but also posed new problems for evolutionary theory. De Vries argued that Mendelian genetics provided support for discontinuous variation rather than Darwinian gradualism. On the basis of his misinterpretation of primrose hybridization experiments he thought that mutations—the sudden emergence of new characters—drove the evolutionary process. These new characters were then passed on in Mendelian fashion. Other scientists opposed de Vries's mutation theory and continued arguing for gradual variations. The dispute over gradualism versus discontinuous variation was only settled in the 1930s and 1940s with the integration, known as the neo-Darwinian synthesis, of Darwinian natural selection theory with Mendelian genetics.

Implications for religion

The religious implications of Mendel's theory were minimal, so no significant religious opposition to

Mendelian genetics arose. However, in the early twentieth century, many eugenics proponents began using Mendelian genetics to promote various programs to control human heredity, including sterilization, birth control, incarceration, and regulation of marriage certificates. The Roman Catholic Church and some conservative Protestants opposed eugenics, but they did not criticize Mendelian genetics. Rather they rejected eugenics as a misuse of genetics.

Probably the most significant connection between Mendelian genetics and religion was the use of Mendelian genetics by creationists. Many creationists hailed Mendel's theory of heredity as a proof for biological stasis. The variations that Mendel (and de Vries) observed only involved the reshuffling of hereditary characters (genes) that were already present, not the introduction of new traits. They rejected the neo-Darwinian synthesis, which argued that micro-mutations could accumulate to produce speciation.

Mendel's life and the reception of his ideas demonstrates the way that religious communities and individuals in nineteenth and early twentieth-century Europe often nurtured scientific discovery. They were not only open to new scientific ideas, but in some cases actively cultivated them.

See also CREATION SCIENCE; EUGENICS; EVOLUTION; GENETICS

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METAPHOR

The word *metaphor* (from the Greek *metaphor,* meaning "transfer") is an important language element in both science and religion. Since the time of the ancient Greek philosopher Aristotle, it has been understood that something strange happens in the process of creating a metaphor. Metaphors change the ways people understand things.

Common definitions of the terms *metaphor, simile,* and *analogy* are not discrete; they refer generally to the substitution of one thing for another. Authors sometimes use one term to refer to all three. For example, in his *Imagery in Scientific Thought* (1987), Arthur I. Miller makes heavy use of the concept of analogy but uses the terms *metaphor* and *metaphorical,* perhaps preferring the complexity, inscrutability, and sophistication of the term *metaphor* over the more mundane, even pedestrian, character of *analogy.* Among cognitive scientists, George Lakoff and Mark Johnson explore implied analogy as a window into the operations of thought calling it metaphor in *Metaphors We Live By* (1980).

Metaphors, however, are less widely found in science and religion, the composite interdisciplinary field of academic study. When metaphor is found in science and religion (the composite field of academic study), the relevant analysis is epistemological rather than aesthetic. That is not to say that the celebrated transfer of meaning, which metaphor is traditionally understood as effecting, is not of importance in the literature of science and religion. It is to observe merely that the linguistic object called a *metaphor* is of less importance than the cognitive process that brings about the transfer that creates new meaning. Accordingly, this entry will emphasize the process—metaphoric process—that brings about the changes in meanings that are found when science and religion are taken to be related and interacting cognitive fields of meaning.

Metaphor and analogy

An important first step is to distinguish metaphoric process from the making of analogies—the business of comparing two things that have similar characteristics. When one of two such things is understood and the other is not, one's overall understanding can be improved by making an analogy. One could say, for example, "Theology in religion is analogous to theoretical physics in natural science." Here one is making an analogy between a component of religious scholarship and a component of research in natural science. For those who know some of the theoretical laws of physics, the character and role of theology in its domain is clarified; the reverse occurs for those who read or write theology. We are here asserting an analogical relationship between a known and an unknown, in which the analogical statement advances understanding by comparing an unknown element with a element previously known. Analogical process dominates much of formal instruction. Metaphoric process is significantly different; it occurs infrequently in the field of science and religion taken together.

Metaphoric process presupposes two different phenomena (*X* and *Y*), each well understood within their respective field of meanings. A discovery then occurs, a gestalt-like realization that the different phenomena are the same. The effect of the discovery is to establish a host of new relationships between ancillary phenomena in the two fields, ancillary phenomena closely related with the original phenomena. Events (discoveries) of this kind serve to knit together the fabric of disparate disciplines, but not by making compromises in which one "side" must relinquish some point to gain some other. Rather, the disparate views are held together and resolved into a higher viewpoint, to use an expression of Bernard Lonergan's, much as binocular vision resolves two different flat images into a single three-dimensional view.

Many scholars, including Mary Hesse, Nelson Goodman, Paul Ricoeur, and Earl MacCormac, address the problem of understanding the metaphoric process in terms of an implied model of thought. For Hesse there is a "network of meanings"; Goodman spoke in terms of "worldmaking"; Ricoeur referred to "shift in the logical distance"; and MacCormac made use of what he called "a computational metaphor for cognition."

Metaphorical processes

Janet Martin Soskice has pointed out that religious metaphors retain their tension long after other kinds of metaphors have lost theirs. One of the most startling and perennially productive religious metaphors is the assertion in John's Epistle that "God is love" (1 John 4:8). The equation of God and love involves equating the field of traditional attributes associated with God, such as superlative potency and intelligence, with the field of meanings associated with love, here understood as human relationality at is best, including vulnerability.

In science, Isaac Newton (1642–1727) used metaphoric process by equating the mechanics of the heavens with the mechanics of earthly objects, thus generating a higher viewpoint that had a profound effect on people's lives. The "laws of the heavens" had been developed earlier by Johannes Kepler (1571–1630). These laws described, in quantitative terms, the motion of the planets (the "wandering" heavenly bodies) around the sun. Mechanical "laws of the of the world" (on the surface of Earth) were given by Galileo Galilei (1564–1642), who could, for example, calculate the motion of a projectile or the rate of fall of an object as it fell toward the ground. Subsequently Newton, in the famous falling apple allegory, realized that Galileo's laws of falling applied to the moon as well as to terrestrial objects, and, with that metaphoric act, caused the laws of Earth to become the laws of heaven—quite a reversal. The general laws of mechanics followed, and the resulting ability to analyze mechanisms and predict mechanical behavior reliably can be understood as having reshaped one world of meanings to create a new world of meanings, one that dominated science and technology for over two hundred years.

Other examples of metaphoric statements can be found. Examples in physics include: heat is motion (Benjamin Thompson, James Prescott Joule); light is particulate as well as undulatory (Albert Einstein); energy is particulate (Max Planck, Niels Bohr, Einstein); and mass is undulatory as well as particulate (Louis de Broglie). Examples in religion include: in the midst of life we are in death (Paul); an individual's ultimate concern is that person's god (Paul Tillich); the "natural" state of existence for human beings is to be graced (Karl Rahner); and Christ is *sophia* and logos (Elizabeth Johnson). Possible examples in science and religion include: evil is entropic degradation and personal relativistic time is the time of the second coming of Christ.

The discovery that two persons from different disciplines are talking about the same thing is not uncommon in closely related fields and can be highly profitable. The exchange interactions of quantum physics were found to correspond to the molecular bonds of chemistry, and chemical physics was born. It remains to be seen whether productive instances can be found in disciplines separated by as much cognitive space as natural science and religion. The hope for science and religion as a valuable academic discipline in its own right depends on such possibilities and on the metaphoric process that can knit them together.

See also MODELS

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METAPHYSICAL NATURALISM

See NATURALISM

METAPHYSICS

The term *metaphysics* refers to the study of things that are removed from sense perception. Modern metaphysics studies the kind of things that exist and the way they exist.

In the dialogue of science and religion, *metaphysics, science,* and *religion* do not necessarily refer to separate endeavors that need relating. Religious faith, for example, can be pervasive so that nature is seen as divine creation and science as a form of worship. Neither do the terms refer to universal bodies of knowledge and belief independent of context. Metaphysics has affected the dialogue between science and religion. These effects have depended on the content of metaphysics and on whether it functioned as science or religion. Moreover, metaphysics and religion have shaped epistemology. Metaphysics has served as presupposition, sanction, motive, criterion for theory choice, criterion for the choice of kinds of explanation (regulative principle), and as part of explanations (constitutive principle). The focus in the dialogue between religion and science is on how God interacts with the world, and on the relation between knowledge of God (religious knowledge and the systematic reflection on it in theology) and knowledge of nature (views of nature, as well as the systematic development of empirical knowledge).

Ancient Greek metaphysics shaped the understanding of God's action in the world in each of the three Abrahamic religions. (Eastern Orthodoxy is an exception in this respect while Judaism can be said to have been only insignificantly influenced.) In Christianity and Islam, the possibility of dialogue between religion and science depended, among other considerations, on how the relationship between theory and observation was envisioned. For ancient Greek philosophers, reliable knowledge was knowledge of the ultimate. Different types of metaphysics had preferred ways of knowing ultimate reality. The Platonic ideas were best known by reason. For Democritus, the random movement of atoms was ultimate reality; their material combinations were best apprehended by sensation. Sensation was also the only source of knowledge of nature for the nominalists, who denied the existence of universal ideas. This reinforced the distinction between observation and reason in eleventh- and twelfth-century scholasticism. To protect divine intervention from naturalistic explanation, theologians distinguished between God's ordained power operating in regular natural phenomena and his absolute power manifested in miracles. In addition, reasoning in theology was limited to avoid conflict with divinely revealed knowledge. Thus the possibility and nature of dialogue between science and religion came to depend on how the relationship between nature and supernature was envisioned.

Metaphysics affected the dialogue between natural philosophy and religion via the content of both. While in Greek metaphysics the order of nature was autonomous and necessary, in the Abrahamic religions it depended totally upon the creator. These traditions were combined by medieval Christian theologians. They acknowledged both a relative autonomy of nature (God's ordinary power) and a divine sovereignty (God's absolute power). Yet theological responses also included the naturalism of William of Conches (c. 1080–c.1150). This set the stage for future discussions. One question was whether purpose in organisms reveals God's natural or supernatural action. Thomas Aquinas (c. 1225–1274) interpreted Aristotle's natural final cause as divine providence, thereby creating a link between natural philosophy and religion. When natural philosophers took purpose as a natural cause, theologians saw the power of God diminished. In response, different forms of voluntarism developed in both Muslim and Christian theology in which creatures were denied causal power because it detracted from God's power. When theologians insisted on God's purposive action in organisms, natural philosophers indicated that God could act through natural law. Responses to these questions regulated the content of both theology and natural philosophy. If animals generate their own purposes, Aquinas considered, inanimate things could prove God's existence more convincingly. Therefore, Aquinas excluded animals from his teleological proof for the existence of God. William Harvey (1578–1657) believed that everything has a God-given purpose. He reasoned that venous valves were created pointing in the same direction in order to prevent reverse flow and to assure the continuous circulation of blood.

In Western Christianity, the idea of absolute divine power did not discourage the exploration of nature's regularities because it was balanced by the idea of ordained power. No such balancing act occurred in the Ashirite school of Muslim theology even though it distinguished between Allah's absolute power and the derived power of humans. This distinction was not applied to natural phenomena. The Ashirites believed Allah creates a cause especially for the occasion of a phenomenon according to a regular pattern of cause and effect. This pattern, however, could be interrupted by prayer. Therefore, knowledge of this pattern remained unreliable even though it was believed to be implanted in the believer's mind by God. Western distinctions between sensation, reason, and faith as ways of knowing became separations. Thus raising the question of their relationship.

The answer further illustrates how metaphysics has affected the dialogue via epistemology. According to the German philosopher Immanuel Kant (1724–1804), scientific knowledge of phenomena arises when sensations are organized by the mind using concepts such as space, time, and cause. Beliefs about nature become scientific knowledge if they correspond to phenomena. Since beliefs about God do not result from sensations they can be accepted only on faith. This separated scientific and religious knowledge into different categories so that no dialogue was possible between them. This separation became an issue in the engagement between religion and biology. The German anthropologist Johann Friedrich Blumenbach (1752–1840) used purpose as a natural secondary cause in explanations of animal development and saw God as the primary cause. For Kant, however, this meant that supernatural causes had been included in explanations of nature. That is, the religious belief that God had created things for a purpose had constituted a scientific explanation. Kant was willing to accept only the regulative use of purpose as a guide to research.

The existence of purposive behavior in organisms is described by a concept of goal or function that excludes from scientific explanation both divine and animal intent. It is used both to guide research (what is the function of venous valves?) and to explain the observations (the function of venous valves is to block reverse flow). In twentieth-century positivism, metaphysics and religion were denied the status of knowledge and meaning because their concepts were believed not to refer to sensible realities. However, Kant's separation and its positivistic interpretation failed for a variety of reasons. As a result, there is renewed interest in metaphysics, which has revealed that it often mediates between science and religion.

See also DUALISM; EPISTEMOLOGY; KANT, IMMANUEL; MATERIALISM; NATURALISM; NATURE; ONTOLOGY

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MILLENNIALISM

Millennialism constitutes the belief that at some point in the future the social world will be transformed into a utopian world of peace, justice, prosperity, and fellowship. The revolutionary quality of the idea derives from the focus on this "worldly" transformation (as opposed to the "other-worldly" promises of spiritual salvation after death) and its ultimately optimistic vision of a humanity that is redeemable "in the flesh." The vision takes both religious forms, such as Christianity's "thousand year reign of the saints," and secular forms, such as utopianism, communism, and Nazism. Both because it has always proved wrong (that millennium has still not arrived) and because of its radical and often violent forms, millennialism has provoked the hostility of many people, especially writers who view it retrospectively. As a result, millennialism has left only a vestigial trace in the documentary record, and it seems to have played a significantly larger role in the oral discourse and actions of the time, especially during periods before the expectations proved false. Historical writing was a hostile medium for the recording of millennial passions, and retrospective accounts often strip millennial commitments from major figures such as Charlemagne and Isaac Newton. Historians have just begun to reconsider this body of documentation and assess its larger role.

Millennialism is, at base, a profoundly optimistic view of a perfectible future. It takes a wide variety of forms, from a hierarchical vision of imperial perfection imposing order and harmony from above, to a demotic world of "holy anarchy" where there is no state and self-regulating saints live in perfect equality. Moreover, the anticipated apocalyptic transformation that moves humankind from its current "fallen" condition perfection can range from a cataclysmic one of immense destruction that leaves only a tiny remnant of saved "saints," to a vast, pacific, and voluntary transformational one that embraces "all the nations of the world" which no longer "lift up sword against [other] nation[s], nor study war any more" (Isa. 2:2–4; Mic. 4:1–4). Finally millennialism can endorse various combinations of a *passive* stance, in which, for example, God will act and humans should wait in penitence, or an *active* stance, in which chosen agents fulfill God's apocalyptic vision. Depending on how peaceful or violent the apocalyptic scenario, active behaviors can range from revivalism and proselytizing (e.g., Peace of God in France, 980s–1030s; Year of the Great Allelulia in Northern Italy, 1233; the Great Awakenings in America, 1730s–1740s and 1820s–1840s) to holy war and genocidal slaughters of the enemies of good (e.g., the Crusades of the eleventh to thirteenth centuries; the Jihads of the seventh century onward; totalitarian purges of the twentieth century).

Although in contemporary usage the term *millennialism* refers to any form of *this-worldly* collective salvation, its original meaning, from the Latin *mille* (one thousand) and *anni* (years), came from the marriage of messianic expectations and apocalyptic "world-ending" beliefs in the crucible of postexilic Judaism under the rule of first Persian, then Greek, then Roman imperial authorities. Here the Babylonian notion of a "great cycle" of seven (planetary) thousand-year ages joined with the biblical notion of a seven-day creation to produce a vision of the fate of the physical universe (creation) from genesis to consummation, passing through six thousand-year days/ages of travail, and climaxing at the completion of 6,000 years with the advent of the *sabbatical millennium,* the thousand years where the "saints" would reign.

Millennialism and chronology

This marriage of millennialism with chronology became especially strong in early Christian circles, and contributed significantly to the immense interest of Western Christian chronographers in precisely calculating both the history of the world and the patterns of yearly and liturgical cycles (*computus*), with which the larger cycles were expected to harmonize (which they do not). For the first thousand years of Christian history, the sabbatical millennium served primarily to delay apocalyptic expectations of an imminent end by using chronologies that pushed the apocalyptic year off by centuries.

Problems arose when the several-century long buffer of the anti-apocalyptic early adopters of the *era mundi* (the age of the world) approached its end, leaving those who inherited these increasingly apocalyptic chronographies in their sixtieth century. Although scholars have not yet been able to get a sense of the process in any detail, the long-term record over the course of the first Christian millennium (first to eleventh centuries) indicates clearly that at the approach of the millennial date, chronographers chose to "correct" their calculations, consistently adopting new systems that "put off" the end yet another several centuries. Thus, around 200 C.E., chronographers adopted an *era mundi* that located the present in 5,700 and the year-6,000 in 500 C.E. At the approach of that date in the fifth century, chronographers adopted a second *era mundi* that pushed the year-6,000 off until 801 C.E. At the approach of this second millennial date in the eighth century, chronographers adopted the *anno Domini* system, putting off the end the current millennium (and, by implication, the sixth and last "age") another two to three centuries to the year 1000 or 1033. These crises, inspired both by approaching apocalyptic dates and by the intractably asymmetric nature of planetary movement, had the unintended but significant consequence of intensifying Western European abilities to measure time, the only science to progress in the early middle ages.

Transformative apocalyptic beliefs and the "making" of the millennium

The apocalyptic scenarios accompanying the sabbatical millennium tended, as do most Christian and Jewish scenarios, to emphasize passive, cataclysmic apocalyptic expectation, since both the date and the actions were in God's hands. But already by the second year-6,000 (801 C.E., the year following Charlemagne's imperial coronation), there emerged a new and unusual form of active, transformational millennialism that channeled the disappointment of failed expectations into projects aimed at transforming the world. Some of the Carolingian theologians, normally known for their lack of originality, demonstrate an innovation that treats the "mechanical arts" as a form of redemptive knowledge and activity. This attitude reverses a classical disdain in Greco-Roman high culture for manual labor, and reflects a biblical respect for manual labor that was part monastic, part millennial ("swords into plowshares …").

At the turn of the millennium, demotic active millennialism had an extraordinary period of some fifty years (980s to 1030s) in France, during which large crowds gathered in open fields and the weapons-bearing elite took public oaths to exempt the unarmed (peasants and clerics) from their violence and rapine. This wave of popular millennialism, unusually affirmed and encouraged by the ecclesiastical and lay ruling groups (bishops, abbots, dukes, counts, kings), produced the largest active, transformational, demotic millennial movement in recorded history and seems to have aroused a great deal of energy among the commoner class, both in terms of their passion for Christianity and in their economic and social initiatives over the next three centuries.

The rise and spread of radically egalitarian (often heretical) apostolic movements that engaged in technology-based work (e.g., weaving) characterizes the centuries after 1000 C.E., a period of widespread and vigorous social, technological, and economic revolutions in Western Europe that transformed both urban and rural regions over the course of the next three centuries. In this period, especially with the "renaissance of the twelfth century," ecclesiastical writers invoked technology as a salvific and growing body of knowledge, and utopian fantasies appear in which automatons animated with magical arts play prominent roles.

By the late twelfth century, the visionary exegete Joachim of Fiore (d. 1202) had brought a revival of millennial thinking and action back to the most elite ecclesiastical circles with his notion of the dawning of the third age of "spiritual men." The power of this way of reading history as a process of (three) stages, with the present poised on the transition to the final, perfected age, to be brought about by active individuals (spiritual men), has proved one of the most potent in Western history (consider, for example, Karl Marx's historical dialectic). Such a system has remarkable resilience in dealing with disappointment: Every failure could take refuge in a renewal and reformulation of the preparatory project of spreading the working of the spirit. And in each new formulation, the role for human action increased and the role for a God, who did not deliver on the promises that prophets repeatedly made in his name, decreased. This drove European Christians on a steady path from a passive scenario, in which God created the millennium (*premillennialism*), toward an increasingly active, humanly driven one (*postmillennialism*).

And the most effective scenarios—effective not in actually bringing about the millennium, but, in their unintended and long-lasting consequences—involved technology. The millennial origins of the West's peculiar passion for technology seem to derive from a notion that if humankind could regain the knowledge it had before the Fall, it could recreate Eden. While there are multiple traces of this belief in the Middle Ages, its conflict with Augustine of Hippo's (354–430) doctrine of original sin kept it at the margins of official culture. But this desire to regain pre-lapsarian knowledge gained great force in the latter half of the fifteenth century with the translation of the *Corpus Hermeticum,* a Gnostic text from the first century C.E. attributed to Hermes Trismegistus. The self-styled magus, who turned to this text to gain the original knowledge (*prisca theologica*) of humankind, believed that at last the time had come to create and transform nature.

Francis Yates argues that these men, the hermetic *magi,* played a central role in the emergence of modern science, not so much by developing rational thought, but by "changing the will," unleashing the passion for the knowledge to transform and perfect nature. Even Francis Bacon (1561–1626), a vocal opponent of the magi, invoked hopes of pre-lapsarian knowledge through science in his call for the Royal Historical Society, as well as his utopian work *The New Atlantis* (1626). Utopian thought represented the first stirrings of secular millennialism, and, beginning with Bacon, they increasingly featured technology and scientific research. The rational, demythologized scientific tradition that is identified as beginning in the early modern period (sixteenth century to eighteenth century) appears to have arisen as an unintended consequence of this passion for esoteric knowledge. For almost a thousand years, Augustine had enforced on intellectuals the humility of original sin: "Fallen man" should not seek to change this world. That enforced humility ceded to a wave of active, transformational millennial enthusiasm that remains to the present.

The links between activist millennial hopes for creating a more perfect society on Earth and the advancement of science and technology from the fifteenth century onward are legion. The most striking link concerns Isaac Newton (1642–1727), a figure who, retrospectively, represents the giant of modern science and rationality. The millennial visionary poet and artist William Blake (1757–1827) heaped contempt on Newton, describing the constricted view of the world in Newton's cosmogony as "single vision and Newton's sleep." But a closer look at the vast and largely unpublished work into which Newton poured so much energy reveals a man at once *magus* (alchemical work) and classic biblical millennialist (ancient chronology designed to calculate the advent of the *Parousia* [the Second Coming of Jesus Christ]). Similar millennial dimensions can be found when one examines closely the careers of other great scientific figures, revealing the role of millennial hopes as a motivator for the scientist, as well as millennial rhetoric as a useful way to attract large sums of funding. Even Roger Bacon (1219–1294) linked the Antichrist to science as part of an appeal to the pope to fund his projects concerning teaching, learning, and disseminating scientific knowledge.

Modern millennialism and scientific megaprojects

Nor has this millennial dimension waned with time. On the contrary, one of the greatest and most portentous projects in history, the invention of atomic bombs, took place in the framework of a war of democratic Western culture against the aggression of technologically empowered Nazi millennialists (*tausendjähriger Reich* means "millennial kingdom"). The Manhattan Project, the United States initiative during the early 1940s to produce the first atomic bomb, has served as the standard for all subsequent grand scientific projects (e.g., space exploration) that raise enormous funds and create a cultural faith in the powers of science and technology, new stages in the "religion of technology." As an unintended consequence, the atomic bomb has revivified apocalyptic fears of the cataclysmic end of the world, just when conceptual scientific schemata had robbed earlier apocalyptic scenarios of any credibility.

Millennial dreams continue to breathe their inspirations into the great undertakings of modern humans, from the messianic belief in "modern civil society" spread the world over (the biblical quotation "nation shall not lift up sword against nation" is inscribed on a wall at United Nations Plaza in New York) to the fear of the apocalyptic annihilation of humankind, whether from environmental pollution and global warming, nuclear threats from the cold war, or terrorism. But this millennial thinking continues to inspire new directions in science as well. New fields of research, such as artificial intelligence and artificial life, have secured funding by appealing to the millennial dreams of both scientists and their backers. The pioneers of artificial intelligence speak about downloading the brain from the troublesome mortal coil and into nearly immortal silicon bodies, of launching an evolutionary step that would compare with the creation of the universe and the emergence of life, or more modestly, with the emergence of *homo sapiens*. Their visionary enthusiasm, simplistic dualism, and boundless megalomania are typical millennial characteristics and make clear how important it is for scientists to better understand their own millennial past. Then scientists and the broader culture might not make naïve and, in this age of immense technological potency, potentially dangerous choices.

But avoiding the dangers of millennial hubris should not lead, as many rationalists argue, to the jettisoning of the millennial vision. On the contrary, the millennial vision serves as one of the great inspirations for scientific and technological development. As Blake commented in *Marriage of Heaven and Hell* (1790), "what is now proved was once only imagined." Of course, not all that is now imagined will be proved, just as not every millennial idea leads to science. But the reverse—how, how much, and what kind of millennial imagination leads to science?—poses interesting questions, well worth trying to answer.

See also ARTIFICIAL INTELLIGENCE; END OF THE WORLD, RELIGIOUS AND PHILOSOPHICAL ASPECTS OF; ESCHATOLOGY

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RICHARD LANDES

MIND-BODY DUALISM

See DUALISM; MIND-BODY THEORIES; SELF

MIND-BODY THEORIES

Mind-body theories are putative solutions to the mind-body problem. The mind-body problem is that of stating the exact relation between the mind and the body, or, more narrowly, between the mind and the brain. Most of the theories of the mind-body relation exist also as metaphysical theories of reality as a whole. While debates over the mind-body problem can seem intractable, science offers at least two promising lines of research. On the one hand, parts of the mind-body problem arise in research in artificial intelligence and might be solved by a better understanding of the relations between hardware and software. On the other hand, the study of emergence in biological systems may illuminate the mind-body relation.

Mind-body dualism

Dualism, or mind-body dualism, is the theory that both minds and brains exist, and no mind is a brain and no brain is a mind, nor is a mind any part of a brain or a brain any part of a mind. Hinduism and non-Advaitic Vedanta entail mind-body dualism because if the soul migrates through distinct incarnations then it is something that can exist independently of the body. If the fusion of *atman* with *Brahman* preserves *atman*'s individuality, then *atman* can exist without the existence of a human body.

The earliest Western philosopher to endorse dualism was the pre-Socratic Pythagoras (c. 569–475 B.C.E.). He inherited the ancient Egyptian religious doctrine that a nonphysical part of the person survives death, and he believed in the reincarnation of the soul. If Plato (c. 427–347 B.C.E.) is not correctly read as an idealist, then he was a mind-body dualist. In his dialogue *The Phaedo* especially, Socrates advanced arguments for the conclusion that the soul survives bodily death. Aristotle (384–322 B.C.E.) held that the soul is the "form" of the human body. He was nevertheless a mind-body dualist because he insisted that the intellectual part of the soul is immortal, even though he offered functionalist or materialist accounts of affective and sensory faculties.

Orthodox Christianity is not mind-body dualist in that human immortality consists in the hope of bodily resurrection, or the living again of the whole person by the grace of God, not in the immortality of a disembodied soul. Although the term *soul* is sometimes used in the Old and New Testaments it does not there explicitly denote an immaterial mental substance that could exist whether or not the body exists. The soul in this strong metaphysical sense was introduced into Christianity during the fourth and fifth centuries by Augustine of Hippo who, believing Platonism and Christianity mutually consistent and true, sought to fuse them into a single philosophical system. Augustine's synthesis accounts for the subsequent Christian belief in mind-body dualism even though a guarantee of the immortality of the soul would seem to make the hope of resurrection redundant. On the other hand, it might be that some resurrection can only be one's own resurrection if one is or one has a soul. If that is right, the immortality of the soul is a logical presupposition of the truth of Christianity.

The seventeenth-century French philosopher and mathematician René Descartes (1596–1650) argues in his *Meditations* (1641) that the only fact of which he can be certain is that he exists. The evidence of the senses, the truths of mathematics, and the whole physical world are ultimately dubitable, but his own existence cannot be doubted, because if he doubts, then he exists. On these premises Descartes concludes that he is a thing that thinks and that does not depend on the physical world, which includes his own body. Cartesian dualism is the view that each person is essentially a substantial soul that is distinct from the body.

Materialism

Materialism is the theory that the mind is the brain, or nothing over and above the brain. The ancient Greek atomist Democritus maintains that there exist only atoms and the void. Atoms are indivisible material particles and the void is the infinite empty space in which atoms are in motion. If atomism is true, then everything is either an atom or reducible to atoms. If there are minds or mental states then they are reducible to atoms and if atoms are physical then minds are physical.

Thomas Hobbes, the seventeenth-century English political theorist and philosopher, was a foundationalist about geometry: Unless the statements of geometry are true then no statement can be true. Geometry is the mathematics of space so it follows that everything is spatial. If everything spatial is physical then everything is physical, and so materialism is true. Hobbes has an account of how people come to be mislead into dualism or otherwise believing in nonphysical realities. Because a mind does not seem to be straightforwardly a physical object, people falsely assume it is a nonphysical object, but this is an abstraction caused by thinking away just some material properties, notably solidity. Hobbes thinks that if people think of anything they can only think of it as physical. One thinks of a ghost as having certain physical properties, perhaps extension and indeterminate shape. This sort of criticism of putative nonphysical realities was later adopted in the 1930s by the Vienna Circle, who sought to replace religion by natural science.

The mind-brain identity theory was influential from the mid-1950s into the 1980s. The main claim of the British philosopher U.T. Place's seminal 1956 paper "Is Consciousness a Brain Process?" is that consciousness is strictly or numerically identical with a physical process in the brain. The identity in question is a contingent and *a posteriori* one, not a necessary and *a priori* one. Place's claim is not to have proved that consciousness is a brain process, but to have removed *a priori* philosophical objections to it as a scientific hypothesis.

Idealism

Idealism is the theory that only minds exist and that physical objects, including the human body, are dependent on minds or consciousness for their existence. Although nondualistic, Vedanta entails the idealist doctrine that only subjective centers of experience exist and the empirical world is only an appearance. The first systematic thinker who could be construed as an idealist is the pre-Socratic monist Parmenides of Elea in the sixth and fifth centuries B.C.E. Parmenides believed that only what can be thought exists.

Plato insists that the Forms (*eidos*) are nonphysical types or essences that exist independently not only of space and time but the human mind. However, the Forms are in principle graspable by the human mind given appropriate training, and the soul "participates" in them before birth and after death. To the extent that the Forms are ideal, Plato is an idealist because he thinks the empirical world depends upon the Forms for its existence.

The third-century neo-Platonist philosopher Plotinus (205–270 C.E.) is plausibly construed as an idealist because he maintains that the empirical world is ultimately an emanation of the One, which is at least nonphysical and spiritual and possesses mental properties.

The eighteenth-century Anglo-Irish Bishop George Berkeley argues that it makes no sense to claim that physical objects exist independently of the possibility of thinking of them or perceiving them. He also argues that the concept of matter, or a physical substratum of which the properties of a physical object are properties, is incoherent.

The German philosopher Immanuel Kant (1724–1804) is usually read as an idealist because his own name for his philosophy was *transcendental idealism*. However, transcendental idealism is the epistemological doctrine that humans are cognitively constituted in such a way that people may only know things as they appear to them, not as they really are in themselves. People are psychologically equipped to formulate philosophical questions but not to answer them. There are no metaphysical propositions because putative claims about a reality beyond space and time are neither true nor false. So the word *idealism* in transcendental idealism is best read as *antirealism*. In so far as a solution to the mind-body problem may be extracted from Kant's *Critique of Pure Reason* (1781), it entails a repudiation of Cartesian mind-body dualism for misusing the category "substance" outside space and time, and an implicit endorsement of the construction of the mental-physical distinction out of a prior monism of phenomena.

It is in the writings of Kant's successors Johann Gottlieb Fichte (1762–1814) and Friedrich Wilhelm Joseph von Schelling (1775–1854) that transcendental idealism becomes a kind of idealism. Georg Wilhelm Friedrich Hegel's (1770–1831) Absolute Idealism is the doctrine that the multiplicity of kinds and degrees of consciousness are ultimately aspects or shapes (*Gestalten*) of the one ultimate cosmic consciousness called *Geist*. On this thesis, which is partly Brahmanist and partly neo-Platonist, the distinction between mental and physical ultimately depends on *Geist*.

Logical behaviorism

Logical (or analytical) behaviorism is the theory that minds can be reduced to publicly observable bodily behavior. According to this theory, any statement about minds or mental states may be translated into a claim or set of claims about actual or possible bodily behavior that is in principle observable. Logical behaviorism is a reduction of the inner to the outer, the subjective to the objective, the private to the public, the first person singular to the third person singular.

The German-born American positivist philosopher Carl Gustav Hempel (1905–1997) is a logical behaviorist in this defined sense. Austrian philosopher Ludwig Wittgenstein (1889–1951) and British philosopher Gilbert Ryle (1900–1976) offer subtle analyses of the uses of ordinary psychological language designed to show that seemingly Cartesian or introspective language in fact takes on its meaning from shared uses in a public world. In particular, Wittgenstein argues in his Private Language Argument in *Philosophical Investigations* (1953) that there have to be public third-person criteria for psychological ascriptions. Mental concepts cannot take on meaning by a kind of private ostensive definition, a sort of inner private labeling of one's own sensations. In that case, there would be no criterion for the correctness of a putative ascription: There would be nothing it would consist in for the ascription to be true or false. It follows that there are no logically private psychological ascriptions, and mental terms do not take on meaning only from one's own case.

Nevertheless, Wittgenstein would strongly resist being called a behaviorist. Ryle, who in *The Concept of Mind* (1949) argues that the myth of Cartesianism does not have to be true in order for people's psychological vocabulary to be meaningful, was not wholly uncomfortable with the label.

Functionalism

Functionalism is the theory that a mind is a set of states essentially causally related to sensory inputs, behavioral outputs, and one another. Functionalism may be partly understood as an attempt to overcome certain shortcomings of logical behaviorism. Behavior seems neither necessary nor sufficient for mentality. It is not sufficient because it does not follow from the fact that someone behaves in a particular way that they are in a particular mental state. Behavior is not necessary for mentality because from the fact that a person is in a particular mental state it does not follow that they behave in a particular way. Mind does not seem to be behavior. Mind seems to be the inner cause of behavior. The contemporary philosophers David Lewis and Hilary Putnam have argued that being in a mental state is being in a functional state, a state caused by sensory inputs and causing behavioral outputs. Functionalism does not entail a view about the intrinsic nature of a mental state, so in a sense avoids the mind-body problem. However, with the addition of just one extra premise—only physical events may be causes or effects—functionalism is a kind of materialism. Functionalism is consistent with the assumption of cognitive science that a person is best viewed as an information processing system.

Double aspect theories

According to double aspect theories, mind and body are two aspects of some jointly presupposed reality that is intrinsically neither mental nor physical. Dutch-Jewish philosopher Baruch Spinoza (1632–1677) argued that reality has two essential properties: thought and extension, or consciousness and physical size. The totality of what *is* could appropriately be called "God" or "Nature" (*deus sive natura*). As parts of the whole, human minds and bodies are two aspects of an underlying reality. Thought cannot exist without extension, nor extension without thought. As in many double aspect theories, this raises the question of what the underlying reality is if it is allegedly neither mental nor physical. Spinoza's answer is existence or being. However, the concept of existence or being has proved recalcitrant to analysis by philosophers from the ancient Greek Parmenides to Martin Heidegger in the twentieth century.

Bertrand Russell (1872–1970) endorsed two kinds of double aspect theories at different stages of his intellectual career. He endorsed the empiricist view that mind and matter are logical constructions of sense data: the contents of sensory experience as they are directly given. Intrinsically, mind and matter are neither mental nor physical. In *An Outline of Philosophy* (1927) Russell argues that there can be no distinction between mental and physical unless fundamentally there exist events that are not clearly mental or physical. In particular the smallest events postulated by science have no intrinsic mental properties and, on Russell's endorsement of the De Broglie/Shröedinger view of matter, are nonmaterial constituents of matter.

Peter Strawson argues in *Individuals* (1959) that the concept of a person is primitive with regard to the distinction between mind and body. Unless humans are already possessed of the concept of the person as a whole, they are not in a position to draw a mind-body distinction. There is a considerable class of predicates that are not clearly only mental or only physical, for example "is smiling," or "is running."

The philosopher and psychologist William James (1842–1910) invented the term *neutral monism* for the view that there are items neither mental nor physical that are ontologically or epistemologically prior to the distinction between mind and matter.

Phenomenology

Phenomenology offers ways of marking the distinction between mental and physical, and diagnoses of how the mind-body problem is thinkable. Phenomenology is the description of appearances just as they are given to consciousness. Assumptions about their objective reality or causal relations are suspended or bracketed by an *epoché* (Greek: suspension of judgement). The ambition of phenomenology is to show how knowledge, including all scientific, religious, and philosophical knowledge is possible. The philosopher Edmund Husserl (1859–1938) grounded knowledge in the transcendental ego, a subjective source of experience that one's own being ultimately consists in, even after ontological commitment to the empirical human being has been suspended by the *epoché.* The transcendental ego is purportedly neither mental nor physical, and phenomenology is purportedly prior to the drawing of that distinction. However, the construction of the world out of acts of consciousness on some interpretations entails idealism and Husserl sometimes called his own philosophy *transcendental idealism.* As is the case with Kant, however, the claim that consciousness of an object is necessary and sufficient for the objective giveness of that object does not appear to entail that the object is dependent on consciousness for its existence. Husserl's teacher and phenomenological predecessor, the Austrian philosopher and psychologist Franz Brentano (1838–1917), argued that the essence of consciousness is intentionality directedness towards an object.

Twentieth century phenomenologists Heidegger, Maurice Merleau-Ponty, and Jean Paul Sartre all reject the *epoche* and the transcendental ego and argue that the mental-physical distinction is dependent on the fundamental existential category *being-in-the-world.*

Conclusion

The mind-body problem cannot be solved scientifically. The brain is billions of atoms in motion in empty space. No amount of empirical observation and experimental testing will explain how awareness is generated by matter in motion. Although it is obvious that ordinary mental states depend empirically on the brain, their subjective interiority of those same states is scientifically inexplicable. The uniqueness of one's own mind is ultimately explicable only if we are souls.

See also ARTIFICIAL INTELLIGENCE; CONSCIOUSNESS STUDIES; DESCARTES, RENÉ; EMERGENCE; EXPERIENCE, RELIGIOUS: COGNITIVE AND NEUROPHYSIOLOGICAL ASPECTS; FUNCTIONALISM; IDEALISM; MATERIALISM; MIND-BODY THEORIES; MIND-BRAIN INTERACTION; NEUROSCIENCES; PLATO

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STEPHEN PRIEST

MIND-BRAIN INTERACTION

That psychophysical interaction occurs seems obvious. How it occurs seems inexplicable. It is a presupposition of common sense but prima facie inconsistent with science that mental events cause physical events and physical events cause mental events. If a commander's decision is a cause of an air strike, then a physical event has a mental cause. If eating overripe cheese causes vivid dreams, then a mental event has a physical cause. However, if the physical universe is a closed deterministic system, then any physical event is caused by distinct physical events sufficient for its occurrence. If physical causes are sufficient for physical effects, then nothing else is necessary, so no mental cause is necessary for any physical event to happen. It follows that mental causation is redundant in the physical universe.

The Third Law of Thermodynamics states that the quantity of energy in the universe is constant. If there were mental causation, extra energy would be introduced into the universe, so if the Third Law of Thermodynamics is true there is no mental causation.

It is just as scientifically inexplicable how mind, consciousness, or awareness could be produced by the brain. The brain is the most complex object known to exist. Nevertheless, for all its neurological complexity, the brain is only billions and billions of wholly physical atoms moving through empty space. It is hard to see how billions and billions of atoms could give rise to awareness: the reader's own awareness of this page, for example. Consciousness seems to be so radically qualitatively distinct from matter in motion it is unimaginable how it could arise out of it.

It is extremely difficult to specify exactly how it is possible for a neurological event to cause a mental event, or a mental event to cause a neurological event. If there exist both minds and bodies then the logically possible permutations of psychophysical interaction would seem to be these: Minds affect bodies but bodies do not affect minds; Bodies affect minds but minds do not affect bodies; Minds affect bodies and bodies affect minds; Minds do not affect bodies and bodies do not affect minds.

If the mental states of human beings bring about physical effects, then human beings are not wholly explicable in terms of scientific laws. One account of this inexplicability is that humans are spiritual beings. Humans as spiritual beings is explicable in turn if they are made in the image of God. It is then unsurprising if the finite mind-body relation is partly like the infinite God-world relation. If we could understand how the mental and the physical interact in causal relations, some insight might be gained regarding divine creation and divine intervention.

Cartesian problems

The pre-Socratic philosopher Anaxagoras (c. 500–c. 428 B.C.E.) famously claimed that "Mind … causes all things," but he neglected to explain how. Aristotle (384–322 B.C.E) claimed in the *Nicomachean Ethics* that choice is the efficient cause (sufficient condition) of action, so if choices are mental and actions are physical, there is mental causation. Nevertheless, Aristotle provided no account of how mental causation is possible. During the seventeenth century, the French philosopher and mathematician René Descartes argued for two-way psychophysical causal interaction between the immaterial soul and the human body, but he admitted to being incapable of explaining how this was possible.

One solution to the problem is to deny that there is causation in either direction, a view entailed by the psychophysical parallelism endorsed by Gottfried Wilhelm Leibniz (1646–1716), the German philosopher and mathematician, and his French partial contemporary Nicholas Malebranche. Leibniz argued that God has caused a "pre-established harmony" and thereby initiated the causal chain that results in mental events and the causal chain that results in physical events, which are correlated rather like the motions of two clocks, each of which tells the right time and therefore the same time. Malebranche agreed that God initiated both causal chains but claimed further that God intervened to determine the timing of each mental event and each physical event. Malebranche's version of psychophysical parallelism is sometimes called *occasionalism* for this reason. In the monist theory of Baruch Spinoza, the seventeenth-century Dutch-Jewish philosopher, thought and extension are two aspects of one substance and do not interact causally.

Much contemporary work on mental causation is also a reaction to Cartesianism. Descartes's mind-body dualism is rejected, but his recognition of psychophysical interaction is accepted. The attempt is then made to explain how mental causation is possible.

Anomalous monism

The most influential theory of mental causation of the last quarter of the twentieth century was anomalous monism, advocated by Donald Davidson (b. 1917), Professor of Philosophy at the University of California at Berkeley. Davidson argues in his 1970 paper "Mental Events" that mental events cause physical events because they are physical events. Davidson's motivation is to relieve the appearance of contradiction between three principles that he thinks are true: causal interaction, the nomological character of causality, and the anomalism of the mental.

According to the principle of causal interaction at least some mental events cause physical events and at least some physical events cause mental events. For example, if intentions, perceptions, and decisions are amongst the causes of the sinking of a battleship in a naval engagement then a physical event has at least some mental causes. If the perception of a physical object, say a battleship, causes beliefs then a mental state has at least some physical causes. On the principle of the nomological character of causality, if two events are causally related then they always fall under some strict deterministic law. On the principle of the anomalism of the mental there are no psychophysical laws, so there are no strictly deterministic laws relating mental events and physical events as causes and effects.

These three principles are prima facie mutually inconsistent. Seemingly, if mental events cause physical events or physical events cause mental events, then they are related by strict deterministic laws so it is then false that there are no psychophysical laws. On the other hand, it seems that if there are no psychophysical laws then either mental events do not cause physical events, and physical events do not cause mental events, or not every pair of events related as cause and effect falls under strict deterministic laws. Nevertheless, Davidson aims to reconcile the three principles by his anomalous monism.

Anomalous monism entails that mental events are identical with physical events. Every mental event is identical with some physical event, but not every physical event is identical with a mental event. Mental events are causes of physical events because they are physical events, and physical events cause physical events. Nevertheless, Davidson rejects the thesis that there exist psychophysical laws. According to nomological monism every mental event is a physical event, and there are psychophysical laws. Davidson accepts the first part of this statement but not the second. According to nomological dualism, no mental event is identical with any physical event, but there are nevertheless psychophysical laws because, for example, mental events are correlated with physical events in some close and invariable way that falls short of identity. Davidson rejects both parts of this. According to anomalous dualism (or Cartesian dualism) no mental event is identical with any physical event and there are no psychophysical laws. Davidson accepts the second part of this but not the first.

If there are no strictly deterministic psychophysical laws then there is no physical explanation of the mental. For example, it is not possible to predict someone's mental state given a complete knowledge of their physical state, or even a complete knowledge of their present and past physical states, or even a complete knowledge of the prior state of the physical universe. If there are no psychophysical laws then no mental events may be subsumed under strictly deterministic scientific generalizations.

If the mental is anomalous then room seems to be left for human freedom. If there is no strict deterministic law relating one's choices or decisions to physical events then they are not necessitated by physical events. Indeed, if one's choices and decisions may cause physical events then one's mental states are at least amongst the causes of one's own actions and, arguably, this is part of what it means for a person to have free will, to be an autonomous agent.

Supervenience

Davidson holds that the dependence of the mental on the physical is very close. The mental is supervenient on the physical. This means that if two mental events differ in some mental respect then they cannot only differ in that mental respect but must differ in some physical respect. However, if they differ in some physical respect it does not follow that they differ in any mental respect.

The doctrine that some property *F* supervenes on some property *G* is expressed by a cluster of views, because the supervenience relation admits of variants and degrees. First, if being *F* supervenes on being *G,* then if two objects—*a, b*—are indiscernible with regard to being *F,* then they are indiscernible with regard to being *G.* So, if the mental supervenes on the physical then it is not possible for two persons to be indiscernible with regard to some mental property without being indiscernible with regard to some physical property.

Second, if being *F* supervenes on being *G,* then if *a* is *F* and *b* is exactly like *a* in being *F,* then *b* is *G.* So, if two people share a mental property then they share a physical property. Third, if being *F* supervenes on being *G,* then *a* cannot change with respect to being *F* without changing with respect to being *G.* So a person cannot change in any mental respect without changing in some physical respect. It is unclear how much is entailed by "without changing with respect to being *G*", but arguably if being *F* supervenes on being *G,* then *a* cannot cease to be *F* without ceasing to be *G.* In that case, a person cannot cease to posses a mental property without ceasing to possess a physical property. Also arguably if being *F* supervenes on being *G,* then *a* cannot begin to be *F* without beginning to be *G.* In that case a person cannot gain a mental property without gaining a physical property.

Weak supervenience is the doctrine that if in the actual world *a* is *F,* then in the actual world *a* is *G.* So if the mental is weakly supervenient on the physical, then if a person has a mental property in the actual world, then they have a physical property in the actual world. *Strong* supervenience is the doctrine that if in every possible world *a* is *F,* then in every possible world *a* is *G.* So if the mental is strongly supervenient on the physical, then if a person has a mental property in every possible world, then they have a physical property in every possible world.

Arguments for supervenience are harder to find than formulations. The supervenience of the mental on the physical is designed to capture the "intuition" that mental facts depend on physical facts but physical facts do not depend on mental facts. It also seems to promise dependence without reduction: Mental events are not nomologically reducible to physical events because there are no psychophysical laws. Mental events are not logically reducible to physical events because it is not true that any sentence or set of sentences about mental events can be translated into a sentence or set of sentences about physical events without loss of meaning.

Even though the mental supervenes on the physical there can be no hope of a reduction of psychology to neurology in the way in which, arguably, biology may be reduced to chemistry and chemistry reduced to physics.

Epiphenomenalism and psychophysical laws

It is objected to anomalous monism, notably by the Canadian philosopher Ted Honderich (b. 1933), that on this theory mental events do not cause physical events "in virtue of" being mental events but in virtue of being physical events. The mental properties of the mental events are not causally efficacious. Honderich points out that some pears on a weighing scale depress the scale in virtue of their physical property of being a certain weight, not in virtue of, say, being green. If this sort of objection is right then in anomalous monism the mental properties of mental events do no causal work. Mental causation has not been explained because nothing mental qua mental is causing anything physical.

Anomolous monism arguably collapses into a kind of epiphenomenalism: the theory that mental events are caused by physical events but physical events are not caused by mental events. In reply it might be urged that the sentence "Mental events cause physical events" is true according to anomalous monism because mental events cause physical events because they are identical with physical events that cause physical events.

It has been argued, notably by Honderich in his *A Theory of Determinism* (1988), that the neurological is sufficient for the mental: The occurrence of some neurological event is a sufficient condition for the occurrence of some psychological event and, as is logically entailed by this, the occurrence of that psychological event is a necessary condition for the occurrence of that neurological event. On this view there seems to be no reason in principle why psychophysical laws should not be discovered because true sentences about neurology would entail true sentences about psychological events. It ought then to be possible to predict the occurrence of psychological events from knowledge of neurological events.

It is empirically uncontroversial in the case of human beings (if not souls, computers, and deities) that the neurological is necessary for the mental. Neurological impairment leads to psychological impairment. If the neurological is necessary for the mental, then the mental is sufficient for the neurological. Arguably the dependency of the mental on the neurological is ultimately an empirical and contingent one. If computers, souls, or God have mentality but no neurology, then it is not a necessary truth that the mental depends on the neurological.

Karl Popper (1902–1993) has argued that the self-conscious mind is an evolutionary product of the brain that nevertheless acts causally upon it. However, if mental events are sufficient for neurological events and if the physical universe is a closed deterministic system, then neurological events are overdetermined. Some event is overdetermined if at least two conditions sufficient for its occurrence obtain. This would seem to make either mental causes or neurological causes redundant. If a neurological event is sufficient for the occurrence of a neurological event then no mental event is necessary for it. If a mental event is sufficient for a neurological event then no neurological event is necessary for it.

One solution, adopted by the contemporary English philosophers Tim Crane and D. H. Mellor for example, is to give up the assumption that the universe is a closed deterministic system. Crane and Mellor see no reason in principle why there should not exist psychophysical laws as scientifically respectable as physical laws.

See also CONSCIOUSNESS STUDIES; DESCARTES, RENÉ; DETERMINISM; EXPERIENCE, RELIGIOUS: COGNITIVE AND NEUROPHYSIOLOGICAL ASPECTS; FUNCTIONALISM; MIND-BODY THEORIES; NEUROSCIENCES; SUPERVENIENCE

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STEPHEN PRIEST

MIRACLE

In order to differentiate between the customary way in which God acts and his special miraculous action, theologians have traditionally distinguished his *providentia ordinaria* from the *providentia extraordinaria,* the latter being identified with miracles. Since the dawning of modernity, miracles have been widely understood to be "violations of the laws of nature." But so long as laws of nature are taken to be universal inductive generalizations, the notion of a violation of a law of nature is incoherent, since such statements must take account of everything that happens, so that exceptions to them are impossible. Although this fact led some Enlightenment philosophers to think that miracles can thus be defined out of existence, it ought rather to alert one to the defectiveness of the modern definition. Natural laws have implicit *ceteris paribus* conditions, so that a law states what is the case under the assumption of certain ideal conditions. If God brings about some event that a law of nature fails to predict or describe, such an event cannot be characterized as a violation of that law, since the law is valid only on the assumption that no supernatural factors come into play.

Miracles, then, are better defined as naturally impossible events, that is to say, events that cannot be produced by the natural causes (i.e., those described by physics) operative at a certain time and place. Whether an event is a miracle is thus relative to a time and place. Of course, some events may be absolutely miraculous in that they are at every time and place beyond the productive capacity of natural causes.

Possibility of miracles

What could conceivably transform an event that is naturally impossible into a real historical event? Clearly, the answer is the personal God of theism. For if a transcendent, personal creator exists, then this God could cause events in the universe that could not be produced by causes within the universe. Given a God who created the universe, who conserves the world in being, and who is capable of acting freely, miracles are evidently possible.

A widespread assumption persists that if historical inquiry is to be feasible, then one must adopt a sort of methodological naturalism as a fundamental historiographical principle. This viewpoint is a restatement of Ernst Troeltsch's principle of analogy, which states that the past does not differ essentially from the present. Though events of the past are, of course, not the same events as those of the present, they must be the same *in kind* if historical investigation is to be possible. Troeltsch realized that any history written on this principle will be skeptical with regard to the historicity of miracles.

Theologian Wolfhart Pannenberg, however, has persuasively argued that Troeltsch's principle of analogy cannot be legitimately employed to banish from the realm of history all non-analogous events. Properly defined, analogy means that in a situation that is unclear, the facts ought to be understood in terms of known experience; but Troeltsch has elevated the principle to constrict all past events to purely natural events. But that an event bursts all analogies cannot be used to dispute its historicity. Troeltsch's formulation of the principle of analogy destroys genuine historical reasoning, since the historian must be open to the uniqueness of the events of the past and cannot exclude events a priori simply because they do not conform to present experience. When myths, legends, illusions, and the like are dismissed as unhistorical, it is not because they are non-analogous, but because they *are* analogous to present forms of consciousness having no objective referent. When an event is said to have occurred for which no analogy exists, its reality cannot be automatically dismissed; to do this one would require an analogy to some known form of consciousness lacking an objective referent that would suffice to explain the situation. Pannenberg has thus upended Troeltsch's principle of analogy such that it is not the *want* of an analogy that shows an event to be unhistorical, but the presence of a positive analogy to known thought forms that shows a purportedly miraculous event to be unhistorical. In this way, the lack of an analogy to present experience says nothing for or against the historicity of an event. Pannenberg's formulation of the principle preserves the analogous nature of the past to the present or to the known, thus making the investigation of history possible, without thereby sacrificing the integrity of the past or distorting it.

Identification of miracles

The question remains whether the identification of any event as a miracle is possible. On the one hand, it might be argued that a convincing demonstration that a purportedly miraculous event has occurred would only succeed in forcing the revision of natural law so as to accommodate the event in question. But a natural law is not abolished because of one exception; the anomaly must occur repeatedly whenever the conditions for it are present. If an event occurs that is anomalous and there are reasons to believe that this event would not occur again under similar circumstances, then the law in question will not be abandoned.

On the other hand, it might be urged that if a purportedly miraculous event were demonstrated to have occurred, one should conclude that the event occurred in accordance with unknown natural laws. What serves to distinguish a genuine miracle from a mere scientific anomaly? Here the religio-historical context of the event becomes crucial. A miracle without a context is inherently ambiguous. But if a purported miracle occurs in a significant religio-historical context, then the chances of its being a genuine miracle are increased. For example, if the miracles occur at a momentous time and do not recur regularly in history, and if the miracles are numerous and various, then the chances of their being the result of some unknown natural causes are reduced. Moreover, some miracles (e.g., the resurrection of Jesus) so exceed what is known of the productive capacity of natural causes that they could only be reasonably attributed to a supernatural cause. Thus, while it is difficult to know in many cases whether a genuine miracle has occurred, that does not imply pessimism with respect to all cases.

See also DIVINE ACTION; GOD; NATURALISM; LAWS OF NATURE; PROVIDENCE; SPECIAL DIVINE ACTION; SPECIAL PROVIDENCE; SPIRITUALITY AND FAITH HEALING;

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WILLIAM LANE CRAIG

MISSING LINK

The term *missing link* refers to an idea derived in a fairly obvious manner from the "Great Chain of Being": a concept, much beloved of medieval scholars and theologians that traces its roots back to Aristotle. According to this notion of an inherent organismic *Scala Naturae,* all living creatures are ranked (or occupy positions) from "lower" to "higher," with humans, the crowning glory of creation, at the top (though between humans and God lie angels, archangels, and other spiritual beings). This archaic terminology still survives in some areas of science today, with vertebrates, for instance, continuing to be classified by many as "lower" (fish, amphibians, reptiles) versus "higher" (birds, mammals).

The metaphor of a chain of being, with its lowest members connected to the highest by an insensible gradation of intermediate forms, naturally adapts to the notion of a series of links. Thus in pre-Darwinian times it was widely held that every species must represent a link in this chain, just as it occupied its own preordained place in nature; some mid-nineteenth century naturalists, though, working in a world whose immensity and diversity were already becoming recognized, vaguely envisaged the eventual discovery of a complete set of living intermediates. With the advent of the notion of evolution by natural selection propounded by Charles Darwin (1809–1882) and his younger contemporary Alfred Russel Wallace (1823–1913) in 1858, and influentially enlarged upon by the former in *On the Origin of Species* in 1859, interpretation of the fossil record, already long known, assumed a new dimension. Earlier western scholars had tended to the view that the ancient fossil organisms, often very different from those familiar in the modern world, were best interpreted as victims of the Noachian flood—or, in view of the evidently complex stratigraphy involved, as witnesses to a series of "catastrophes" for which biblical authority was sought. With the introduction of the concept of evolution, an alternative explanation was at hand: that extinct organisms represent stages along the route through time from ancestral forms to the modern biota.

From this point it was but a short leap to the notion of ancient "missing links" in the chain. In popular lore the most famous of these lies between apes and humans, and many fossils have been acclaimed in this intermediate role. Darwin had emphasized in his *Descent of Man* (1871) that today's humans and apes are descended from nothing like an existing ape or monkey, but from a common ancestor (which, by definition, can be neither). Still, the half-human, half-ape image, of a form caught in the act of clawing its way up toward humanity, seized the public imagination, and even that of scientists. Among the latter the influential Ernst Haeckel (1834–1919) went so far as to name this hypothetical form *Pithecanthropus alalus* (the "ape-man lacking speech").

It is useless for paleoanthropologists to protest that if a form is missing, it cannot be a link, and that if it is to be a link, it cannot be missing. It is well known now that it is far more accurate to speak in terms of a ramifying bush of ancestors and descendants than of links in a chain. But it will be a long time before we are able to exorcise the evocative "missing link" from our vocabularies.

See also EVOLUTION, HUMAN

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IAN TATTERSALL

MITOCHONDRIAL EVE

Mitochondrial Eve is the name given to the hypothesis proposed in 1987 by Rebecca Cann and others that all humans are descended from one female who lived around two hundred thousand years ago in Africa. The claim was based on study of mitochondria, parts of the cell (containing genes) that exist outside the central nucleus and that are passed on only by females. It should be noted what is not being claimed, namely that all humans beings are descended from just one woman. Humans could all be descended from many, or just a few, or some from one group and some from another. It is just that all humans share at least one female ancestor, who may or may not have had just one mate. The hypothesis is generally accepted as true although there are questions about the accuracy of the dating. In this respect, future research might demand substantial revision at some later point.

See also EVOLUTION, HUMAN

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MICHAEL RUSE

MODELS

Models are widely used in many disciplines to turn complex or abstract information or ideas into a form that is more easily understood and workable, basically as representations of the information or ideas. A scale model is an actual construction that resembles the original object. Models using analogy or mathematical logic display varying degrees of abstraction. Of the many types of models, several are commonly used in science and theology, though there are differences in their applications in each discipline.

In the natural sciences, the use of models generally implies the idea of interpretation of a deductive system, carried over from mathematical logic. Scale models and analogues are also commonly used, whether similar in substance to the thing modeled or similar in the relations between its parts. Formal analogies show analogy of structure between the model and the system modeled. Material analogies show material similarities between the original system and its model, such as in replicas. Mary Hesse notes that the relation of analogy—formal or material—implies differences, denoted as *negative analogy,* as well as similarities, called *positive analogy*. The billiard ball model of gases offers both positive and negative analogy. From the early part of the twentieth century on, there have been debates over whether models are essential to successful theorizing in the sciences or whether the use of such models is potentially misleading and dispensable.

In theology, models may be utilized in order to better understand doctrines such as the relation between God and the world, as well as doctrines of God or theological anthropology. In the history of theology, it has usually been the practice to speak in terms of analogy or metaphor, tropes of language that serve as a type of "momentary" model. By contrast, Sallie McFague defines models as metaphors with "staying power."

In discussions about the relation between religion and science over the last third of the twentieth century and into the early twenty-first, the use of models has played a highly significant role. Different epistemological models show how the modern period has described knowledge of the world and the status of models in scientific theorizing.

These include *naïve realism* (the model is a literal picture of reality), *logical positivism* (theories are directly deducible from data, dismissing models), *utilitarianism* (models are useful fictions), and *critical realism* (models are representations of reality in interaction with the observer). It is the last that has dominated discussions of the relation between religion and science. By the 1980s, other epistemological models began to be proposed. Challenges to standard interpretations of critical realism have been raised in the light of developments of the late twentieth and early twenty-first centuries. These challenges include postmodern critiques of foundationalism, "science and technology studies" that have expanded upon Thomas Kuhn's concept of paradigm *in The Structure of Scientific Revolutions* (1962) as well as feminist and postcolonial critiques and writings in the sociology of knowledge.

Models are also used in the science and religion dialogue and serve to show how relations between religion and science have been conceived. Most widely used of this kind of modeling is the four-fold typology of Ian Barbour: conflict, independence, dialogue, and integration. Models that include historical examples have come under criticism by historians, who point out that models give only a partial picture. Many argue that misunderstandings occur because models may oversimplify the historical situation. Many recent studies examine and elaborate upon the complexity of the social and political situations that bear upon the perception of a conflict between religion and science.

See also METAPHOR; PARADIGMS; SCIENCE AND RELIGION, METHODOLOGIES; SCIENCE AND RELIGION, MODELS AND RELATIONS

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MODERNITY

The terms *modern* and *modernity* have been widely used in the expression of two contrasting perspectives. They either (1) suggest that certain new habits, practices, or worldviews are inferior to those of ancient, medieval, or classical times and origins; or (2) they claim the superiority of these habits, practices, or worldviews, ascribing a positive meaning to their being new, up to date, fashionable, progressive, or evolutionarily successful.

It is typical of the latter perspective that the emphasis has been on "current" developments and on "the present," and that contrasts such as primitive, old, antiquated, obsolete, as well as terms with the prefix *pre* (e.g., premodern, preindustrial), have been used. This perspective is applied to the most recent social, literary, and aesthetic developments, and it leads to an ideology of permanent qualitative progress.

A major shift between these two views of modernity is marked by the controversy called the *Querelle des Anciens et des Modernes* (Quarrel of the Ancients and the Moderns; a title derived from the writings of Charles Perrault), which began in England and France in 1687 and lasted for about a century. In this long debate several philosophers of the Enlightenment questioned the superiority of antiquity, its arts and values. They thus paved the way for the self-privileging of modernity over the other epochs of human history.

The term *modernity* also designates an epoch in human history that is characterized by the emergence of nation states that build on the political loyalty of their citizens, develop standardizations of the law, and establish legal institutions and bureaucratic forms of administration. Such nation states permit and even encourage public deliberation about the common social order, the common good, and the common goals. This development is connected to a consolidation of knowledge through institutionalized education and with strategies to acquire knowledge systematically by cultivating the "sciences." The political, educational, and scientific processes develop along with an industrial society that by the technological application of scientific knowledge generates a constant transformation of its natural and cultural environments.

Modernity as historical epoch

Since these developments have not occurred simultaneously across the globe, the localization of modernity in space and time is difficult to determine and remains open to debate. The Reformation is often designated, even in secular circles, as the breeding ground of typically modern mentalities. Modernity is also usually associated with the age of "enlightened thinking" that shaped Europe and North America from the second half of the eighteenth century on. During this period, the French revolution and the philosophy of Immanuel Kant (1724–1804) became the most important sources for political and intellectual ideas. During the last decades of the twentieth century, an ongoing international debate about the end of modernity set in, with Friedrich Nietzsche (1844–1900) acting as an early prophet of "postmodernism." The postmodern period is fuelled by the growing conviction that modernity's faith in the unity of reason and the rationality continuum was illusion, and by uncertainties about the future of nation states in the process of globalization.

The ambivalences of modernity

Whereas modernity can be regarded as an endeavor to escape religious and political tyranny and authoritarian traditionalism, it has itself become a metaphor for a deeply ambivalent global enterprise. The striving for liberation, the establishment of a public legal system, mandatory education for all people, and the development of welfare systems within the nation state were all aspects of the modern enterprise. The same modernity that fled the tyrannies of the past and strove for the unity of the state, the rule of law in political life, and political sovereignty based on the will of the people (democratization) also brought forth aggressive nation states characterized by chauvinism, imperialism, colonialism, and ecological brutality. Similarly, the escape from prescientific and even mythical worldviews, the striving for a consolidation of knowledge through the sciences, the search for scientific truth, and the appeal to rationality and reason led to more than the triumph of public education and the flourishing of discovery and technological innovation. It also led to scientistic and naturalistic ideologies that promoted blindness to religious truths and cultural complexity.

Alfred North Whitehead (1861–1947) offered a subtle analysis of how the unfolding and the triumph of scientific thinking shaped the modern common sense, its modes of experience and expectation, and how it correlated with a relative deformation of aesthetic, ethical, and religious experience. According to Whitehead, "The modern world has lost God and is seeking him" (1960, p.72). The process of modernization finally led to the dominance of science-assisted technical reason (industrialization) and to the triumph of the powers of the market, the media, and technology—developments that have turned out to be culturally imperialistic and ecologically destructive.

Ambivalence over the blessings or curses of modernity is rooted in a structural conflict within modernity itself, which has lead to the deeply negative connotations associated with the term *modernity.* The conflict is usually spelled out by the dual of "modernity" and "postmodernity." It is also present in the ongoing discussion of whether postmodernity is merely an extension of modernity, a self-jeopardizing of the modern enterprise that would be better identified as *late modernity.*

On the one hand, modernity strives for the freedom of the person, the equality of all human beings, and for the universality of reason. Modernity's fight for justice and equality, and against tyranny, is connected with a passion for universal transparency and unity. For the modern mind, unity means consensus, mutual understanding, and harmony based on equality. On the other hand, modern societies have developed a multisystemic texture as modernity brought forth a differentiation of social institutions, sciences, and rationalities—differentiations that resist the plea for an overarching universal unity. Modernity thus created an ongoing conflict between unity and differentiation: a passion for unified reason, a universal rationality-continuum, and universal morality on the one hand, and a passion for differentiation of social systems, differentiation of the sciences, and a nonhierarchical differentiation of cultural spheres on the other hand.

Several social systems work for the sustenance and the wellbeing of the whole society. Such systems include, for example, politics, law, religion, education, the sciences, the market, the media, technology, the arts, and the family. In this multisystemic order each system performs a function that is essential and indispensable for the whole society. At the same time each system strives for autonomy and defends itself against interference from other systems. Each system optimizes its procedures, its rationalities, and its institutional forms. Along with the differentiation of the social systems, modern societies developed a rich texture of associations, such as political parties, ideological movements, and a variety of clubs and lobbies, all of which attempt to influence, strengthen, or question and reshape the "division of powers" within social systems. The universal and even grandiose claims of such associations grow out of the interests and goals of their members. Some associations perish quickly, while others have a long life. Some are normatively and institutionally stable, others are open to trends. These associations, which want to influence and actually do influence social systems, make up civil society. The complex, but by no means chaotic, interaction between social systems and civil associations constitutes so-called pluralistic society, which provides a structured and pluralistic setting for the sciences and other cultural formations, a setting that promises to cope with the inner conflicts of modernity.

Modernity and postmodernity

The structured pluralism of modern societies and cultures has brought a differentiation of rationalities: for example, those of the market, of the natural sciences, of historical investigation, of religion, and of common sense. This differentiation has challenged the modern ideal of the universal unity of knowledge and of mutual moral communication and understanding. Yet with its multisystemic setting it has also challenged the idea of an endless and relativistic differentiation and dissociation, an idea often connected with postmodernity. These multisystemic settings appear in many areas of life, although the question of how many social systems there are and how they should be differentiated remains open to debate. But certainly their number is finite and small, and the evolution of a new system takes a long time, as evidenced, for example, by the development of the media during the nineteenth and twentieth centuries. The same holds true for differentiation in the sciences or for the family of confessions in Christianity, which constitute the pluralism of the academy and the pluralism of the ecumene. The world is much more complex than the typical modern mind is willing to admit, but it is much less chaotic than those who hope to exorcise the spirits of postmodernity would have it.

The one clear difference that divides modernity and postmodernity is reflected in many areas and on many different levels: This is the difference between the highest value and the interpretation of this value in both epochs. For modernity, the value of unity is paramount. For postmodernity, the value of difference is crucial. This, of course, includes different understandings and interpretations of *unity* and *difference* on both sides. For the typical modern mind, difference meant conflict, disagreement, inequality, or even oppression. For the postmodern mind, however, difference means freedom and creative engagement, while unity raises suspicions of adaptation, control, and even oppression. The postmodern mind would nevertheless acknowledge that not all forms of difference are creative and helpful. One must differentiate between the differences and recognize that some can be destructive. The postmodern mind would also welcome differentiated forms of unity. But all forms of unity have to allow for difference, have to appreciate and even treasure difference. Otherwise they breed oppressive ideologies.

The postmodern mindset is not simply based on some Nietzschean philosophical idea. Numerous cultural and scientific achievements, along with many experiences of oppression and pain, have led to the conviction and to the affirmation that the world is *poly-contextual*. Society must welcome multiperspectival approaches and should embrace and cultivate pluralistic settings if it wants to maintain the modern striving for truth, justice, and dignity. Different cultures, different traditions, and different rationalities have to be taken seriously.

Moreover, the human individual has to be taken much more seriously than modernity thought.

Modernity praised the value of the theoretical "human subject" and its autonomy, freedom, and rational self-control, but it failed to address the actual unique individual. Rather, modernity had in mind the idealized, standardized person of the bourgeois value system: the autonomous "subject," guided by reason and universal morals. But concrete human beings are much more subtle and complex. They are determined by unique personal histories, by complex biological endowments, by intricate passions and feelings, and by different forms of rationality. Some are more impressed by religion than others; some are devoted to the natural sciences, while others are skeptical of them. Some find their key values in family and friendship; others look for a more general orientation for the common good. The young Friedrich Schleiermacher (1768–1834) recognized the problems in the modern concept of the human person, and he accused Kant of having standardized modern subjectivity and of having attributed too much power to reason. Schleiermacher called for a new conception of individualism, one that takes each multifarious human person seriously—a sort of poly-individualism. In this respect, however, modernity itself provides possibilities for escape and for correcting its own reductionistic anthropological concepts. "All in all, resistance to rationalization has been as prominent a mark of modernity as has rationalization itself" (Bauman, p. 596).

See also POSTMODERNISM; POSTMODERN SCIENCE

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MICHAEL WELKER

MONISM

The term *monism* comes from the Greek word meaning *alone* or *single.* While the term was originally used by German mathematician and philosopher Christian Wolff (1679–1754) to refer to views asserting either that everything is mental (idealism) or everything is material (materialism), monism has wider applicability today, claiming that the various things or kinds of things encountered in the world are somehow reducible to, derivable from, or explicable in terms of one thing (substantival monism) or one kind of thing (attributive monism). The substantival and attributive views are logically independent—e.g., Baruch Spinoza (1632–1677) affirmed the first while holding a plurality of attributes; Gottfried Wilhelm Leibniz (1646–1716) held the second while countenancing a plurality of substances.

Monism must be distinguished from pluralism, which asserts that there are various things or kinds of things. Monism must also be distinguished from dualism, which claims that there are only two basic kinds of things. Often, however, the term monism is used imprecisely to refer to any fundamental dichotomy in a philosophical or religious system (e.g., good and evil, soul and body, male and female). Of particular interest in the science-theology conversation are the apparent dualisms of mind and body, and God and universe.

A primary motivation for monism is ontological simplicity—a world in which there is one basic thing or kind of thing makes fewer ontological claims than one asserting the existence of many things or kinds. Explanation for the monist is homogeneous and coherent; it makes no appeal to entities of a different ontological type when framing its causal stories. Moreover, the assumption of monism (particularly of physicalist variety) has been enormously fruitful. On the other hand, pluralism is motivated by the apparent multiplicity of things and kinds, and the desire to avoid purchasing simplicity at the expense of real complexity. A further advantage of monism is that, unlike pluralism, it does not need to offer an account of a relation that supposedly conjoins fundamentally disparate kinds.

In addition to materialist (physicalist) and idealist monisms, there is also neutral monism and anomalous monism. The first claims that both mental and physical phenomena are manifestations of an underlying neutral stuff. Spinoza and Bertrand Russell (1872–1970) are associated with this position. The second, advanced by twentieth century philosopher Donald Davidson, holds that while every mental event is token identical to some physical event, mental properties can nonetheless not be reductively identified with physical properties. Because mental properties are individuated holistically according to criteria of coherence, rationality, and consistency which, as Davidson notes, "have no echo in physical theory" (p. 231). Although all particulars are physical (physicalist monism), the incommensurability between mental and physical properties requires a property dualism.

Both substance and property dualism are of interest in the science-theology discussion. For example, most would claim that substantival and attributive monism are both incompatible with the substance dualism of divine and worldly stuff (or creator and created stuff) that theism presupposes. Others have suggested that since God can be understood immanently, a dualism of divine and worldly properties is compatible with a monistic ontological physicalism. The question for the science-theology conversation is whether God-universe or mind-body property dualism coupled with physicalist monism has the resources to avoid reductive explanation, and thus successfully to ground an ontology of the mental and the divine.

See also DUALISM; MATERIALISM; NATURALISM; PHYSICALISM, REDUCTIVE AND NONREDUCTIVE; PLURALISM

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DENNIS BIELFELDT

MONOTHEISM

Monotheism is the belief in a single personal God who is the creator of the cosmos and continues to exercise some influence on it. Monotheism is the core tenet of Judaism, Christianity, and Islam, as well as a basic belief about reality for many outside these traditions. God is often, but not always, held to be of unlimited power (omnipotence), unlimited knowledge (omniscience), unlimited extension (omnipresence), and unlimited goodness (omnibenevolence). Further beliefs—God is three persons in one, is self-revealing, is salvifically involved with human beings—are advanced by specific religious traditions; their beliefs about God share important commonalities and exhibit important contrasts.

See also GOD; PANENTHEISM; PANTHEISM; THEISM

PHILIP CLAYTON

MORALITY

Morality (Latin *mores,* from *mos,* implying custom, practice, or conduct) is a standard of character measured against established philosophical or other categories. Morality may be assessed by psychoanalytic and social theory as a degree of superego formation and socialization (Sigmund Freud). It can be seen as a mark of maturity in relation to stages of a cognitive-structural hierarchy (Lawrence Kohlberg). It is often viewed as a level of character formation and responsible self-appropriation (Erik Erikson). Moral self-consciousness is tangible in relation to the customs, manners, and character that constitute life within a shared space (Charles Taylor). The axes of moral reflection can generally be seen as constituted by deontological or teleological considerations, such as questions of obligation (actions, intentions, etc.) or value (respect, dignity, etc.).

See also FREUD, SIGMUND; VALUE

RODNEY L. PETERSEN

MORPHOGENESIS

See EVOLUTION

MUTATION

A mutation in a gene is a structural change in the sequence of nucleotide subunits in the chains that make up DNA. Changing the structure of a gene alters the design information contained in its nucleotide sequence, and generally affects the function of that gene's product. The design instructions for that gene product are spelled out in DNA as a particular sequence of the chemical subunits called *nucleotides,* each of which contains a nitrogenous base: *adenine* (A), *thymine* (T), *cytosine* (C), or *guanine* (G). Hundreds of nucleotides are linked in a DNA chain in the sequence that spells out instructions for a single gene. This is analogous to conveying instructions in printed books by particular arrangements of twenty-six kinds of alphabetical letters. In the case of genes, however, there are only four letters in the alphabet.

Gene products are usually proteins, and altering the design information in a particular gene will alter the structure and function of its corresponding protein. Since proteins do all the body's work, they account for all the biological characteristics (*phenotypes*) of any organism. Usually, a mutation in a gene produces a harmful effect, hindering the function of the protein designed by that gene, and sometimes the hindrance is lethal to the organism. Many cancers and inherited diseases are believed to be associated with mutations. In contrast, very occasionally a mutation may be beneficial. If a beneficial mutation is inherited it could cause progeny to adapt better to their environment than their parents could. Such mutations provide a substrate for natural selection in evolving new or better biological functions.

Mutations are produced from errors when cells copy DNA, or from damage caused by radiation or chemicals. Cells contain mechanisms for repairing DNA, but they are not perfect. Changes in the nucleotide sequence can include substitution of one nucleotide for another, insertion or deletion of one or more bases, or transposition of segments of the nucleotide chain.

Although some nucleotide sequences seem more prone to mutation than others, rules governing the specific location of mutations are not evident. The view that genetic variants are produced by chance, and that natural selection favors variants that best meet the necessities of survival, led to the claim that evolution is the product of mere chance and necessity. This claim was extended theologically to assert that there is no purpose in the universe, and therefore no designer, divine or otherwise. Some challenges to this claim are based on different concepts of chance.

There are reports of mutant genes that predispose their bearers to abnormal behaviors, such as violence or addiction. A complication in the interpretation of such reports is that a behavioral gene, like most genes, would be just one of many factors determining the behavior under consideration. In addition to environment, biological history, and cultural influences, those factors would include other genes having functions coordinated with those of the behavioral gene. Nevertheless claims for the existence of such mutant genes as the so-called violence gene have provoked theological discussion about personal culpability on sin.

See also BEHAVIORAL GENETICS; DESIGN; DNA; EVOLUTION; GENETIC DEFECT; GENETIC TESTING; GENETICS

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R. DAVID COLE

MYSTICAL EXPERIENCE

Defined in contradistinction to so-called ordinary or mundane experience, mystical experience conjures images of ecstatic rapture, overwhelming emotion, or profound quietude. An apparently universal aspect of human experience cross-culturally and interreligiously, subjective experiences of a mystical persuasion likely reflect universal but nonetheless unusual predispositions and propensities of the human mind. Continuing advances in cognitive science in general, and in the neurosciences in particular, promise to illuminate aspects of mystical experience previously hidden behind the mask of the phenomenological. At the same time, a historically more refined form of comparative phenomenology promises to coordinate the enormous variety of descriptions of mystical experiences. Research from both the sciences and the humanities will contribute to the development of a comprehensive, compelling interpretation of these experiences.

See also EXPERIENCE, RELIGIOUS: PHILOSOPHICAL ASPECTS; MYSTICISM

JENSINE ANDRESEN

MYSTICISM

Permeating each of the world's major religious traditions, mysticism may be described as the level of deep, experiential encounter with the divine, or ultimate, however that may be understood, that links religious and spiritual pursuits across cultures and across the centuries. Mysticism differs from more defined forms of religious experience, inasmuch as it frequently transports the individual beyond the confines of the religious tradition itself to a realm often described as lacking in any sense of differentiation, whether it be between aspirant and God, or between self and non-self.

The task of defining *mysticism* bears reevaluation, however. As Frits Staal has written, "If mysticism is to be studied seriously, it should not merely be studied indirectly and from without, but also directly and from within. Mysticism can at least in part be regarded as something affecting the *human* mind, and it is therefore quite unreasonable to expect that it could be fruitfully explored by confining oneself to literature about or contributed by mystics, or to the behavior and physiological characteristics of mystics and their bodies." (p. 123). That being said, according to a loose, phenomenological typology, one may consider mysticism to be that genre of subjectivity and behavior manifesting in an "altered," or non-conventional mode, framed in a religious or spiritual narrative, and experienced by those who are refered to, at least in English, as "mystics."

Mysticism in various religious traditions

The Christian tradition manifests varied branches of mysticism, including the Discalced Carmelites, a movement within the Carmelite order that espouses a form of mystical development still followed today in the Catholic Church. Founded by St. Teresa of Avila (1515–1582) and St. John of the Cross (1542–1591) in sixteenth-century Spain, the movement defended the practice of inner prayer against its persecution by King Philip II of Spain. Educated by Jesuits, John of the Cross began theological studies at the University of Salamanca in 1567 but left to help Teresa of Avila in her efforts to found the Discalced Carmelites. Imprisoned by the non-reformed Carmelites from 1575 to 1578, he used his imprisonment to his advantage, composed poetry, and, finally, escaped to face further suspicion regarding supposed connections to so-called illuministic books roundly condemned during the Inquisition. Only after the Apostolic See had examined his orthodoxy in the early seventeenth century were his books published openly.

St. John primarily articulates a systematic approach to mystical development appropriate to cloister spirituality, though he wrote his last book, *The Living Flame of Love,* for a laywoman, and used it as a vehicle of instructing both lay and monastic Christians in the methods for attaining mystical union. St. John may primarily be remembered for explicating a so-called via negativa mode of spiritual engagement in which one prays without focusing on imagery and without actively pursuing any specific intellectual content (Mallory, pp. 1–7). Some generations earlier, Dominican mystic Meister Eckhart (1260–1328) similarly utilized a kind of "negative theology" to point towards the inadequacy of human language and perception in capturing the fullness of mystical experience: "There is no knowing what God is" (Steere, pp. 143–144). And in the Indian Advaita tradition, as Mahadevan wrote in the preface to *The Wisdom of Unity,* one experiences transcendent unity as "the distinctions and differences that teem this world" fade away in the recognition of "the eternal non-duality of the Self."

The Sufi tradition exhibits the depth of Islamic spirituality and exemplifies the paradoxical quality of mysticism in general. According to Rumi (1207–1273), a Persian mystic and poet, "What is Sufism? He said: To find joy in the heart when grief comes." Rābi 'a (717–801), a Sufi mystic and an Islamic saint, "introduced the element of selfless love into the austere teachings of the early ascetics and gave Sufism the hue of true mysticism." Never marrying and not favoring the prophet Mohammad in any particular way, she loved God absolutely, and completely, losing herself in contemplation of him. Sufism also provides a good example of the nature of the path that carries mystics of all stripes, a series of steps towards a deep experience of God, toward the realization of emptiness, or towards whatever the goal may be. In Islam, Sufis follow the *ṭarīqa* (path), in which the mystic practices *īthār* (preferring others over oneself), a practice that later dissolves as the difference between oneself and the other is "subsumed in the divine unity" (Schimmel, p. 99).

The theme of total, devotional love also infuses Christian mysticism, as evidenced by the Franciscan movement of the *alumbrados,* those mystics "illuminated" by the Holy Spirit, some of whom practiced *dejamiento* (abandonment) of oneself to the love of God, with the result that the formal sacraments of the Church were seen to be superfluous (Hamilton, pp. 1–2). And according to the visions of the German mystic, Hildegard of Bingen (1098–1180), love appears as a beautiful apparition, such that "the fire of God's love runs through the world and its beauties, constantly re-enlivening the cosmos as a miracle of perfection" (Schipperges, pp. 68–69, citing Hildegard's *Book of Divine Works*).

The status of duality, or non-duality, occupies branches of mysticism otherwise separated by virtue of culture, time, or doctrine. This is unsurprising, particularly given the nature of mysticism itself in transcending boundaries, which are often perceived as limitation; for example, the dualisms of sense versus spirit, and attachment to creation versus attachment to God, pervade St. John's writings, as Marilyn Mallory posits in her 1977 book, *Christian Mysticism.* Interestingly, in attempting to express non-duality and paradox, mystics often choose poetry as a modality capable of pointing beyond the mundane levels of a world with defined, black and white borders, at the same time that it promises great aesthetic enjoyment to its listeners. And as Herbert Guenther indicates in *The Royal Song of Saraha* (1969), beginning with Mar pa (1012–1097), Tibetan teacher and translator, the Doha tradition in Tibet utilized melodious verses composed and sung by mystics to both express and indicate non-conventional modes of awareness and states of deep appreciation and joy.

Sometimes referred to as "states of infused contemplation" (Pike, p. ix), union exists as a central preoccupation of many mystics. In Christianity, for example, union covers experiences from prayers of silence, to prayers of union, to more intense experiences of rapture, so-called ecstasy states similar along certain dimensions to shamanic flights of the soul. As Nelson Pike puts it, "the paradigm union experience … unfolds through a dualistic stage into a state in which the distinction between subject and object is lost" (p. 59). Language fails at this important juncture, causing many mystics to resort to metaphor and poetry in describing their experiences. St. John of Ruysbroeck (1293–1381), for example, describes his experience of being permeated, stating, "the iron is within the fire and the fire is within the iron; and so also the air is in the sunshine and the sunshine in the air" (pp. 236–237).

Sociologically, mystical traditions in many religions rely upon a period of tutelage by a respected member of the community, and a period of discipleship on the part of the aspirant. As Frits Staal comments, "The need for a qualified teacher is stressed in almost all the traditions of mysticism .... In Islam it is the foundation of the *silsila* or 'spiritual lineage'" whereas in Indian religions, one refers to "the *guruparampara,* 'the direct lineage of teachers'" (p. 144). Tibet, for example, historically organized a good part of its country's social structure around this kind of hierarchical, lama-discipline relationship, and this tradition of devotion to idealized teachers in some cases stimulates the minds of Western academics who study Buddhism. One also may find the master-discipline lineage tradition in other religions, such as the Sufism of West Africa. 'Umar al-Shaykh (864–960) brought the Qādiriyyah order of Sufism to the western Sudan in West Africa, having been initiated into the order of the Qādiriyyah masters and *hajj,* as Ibrahim Doi posits in "Sufism in Africa" (1991).

In communities, and in some cases, entire societies, in which mystical achievement translates into positions of power and prestige, authenticity exerts itself as a powerful mediator of who will or will not be accepted by the group, which teachings will be honored, and whose interpretations will be valued. In the Islamic world, for example, Jami (1414–1492), a Persian poet and mystic, describes two types of mystics, those who are concerned with their own salvation and who practice in complete reclusion, "and those who return from their mystical experience in a higher, sanctified state of mind and are able to lead other people on the right path" (Schimmel, p. 7). Grace Jantzen also discusses the manner in a "gendered struggle for power and authority" permeates mysticism in early and medieval Christendom, though the same may easily be claimed for mystical traditions more generally (p. xv).

Members of mystical communities also distinguish between "the true Sufi, the *mutasawwif* who aspires at reaching a higher spiritual level, and the *mustawif,* the man who pretends to be a mystic but is a useless, even dangerous, intruder" (Schimmel, p. 20). In some cases, too, the mystic's life is seen to contradict that of the householder, and severe sanctions may ensue. For example, the father of Dnyaneshwar, a well-known fifteenth-century Indian saint, abandoned the world for the mystical path after leading a householder's life for many years. He later returned to family life, however, fathering Dnyaneshwar, who was condemned as an outcaste on the basis of his father's violation of the orthodox injunction that a *sanyasi* (renounced person) should never return to the life of the householder, according to Ian Ezekiel.

Throughout this brief account, the existential dimensions of mysticism should not be ignored. Mystics from all traditions often point towards aspects of reality beyond the conventional world of thoughts and forms. *Yesh,* a Hebrew term used by rabbis to indicate the treasure awaiting saints in the future life, roughly translates as *there is,* thereby signaling deeper existential dimensions than those normally encountered. As Abraham Isaac Kook (1865–1935), a Jewish mystic, writes, "So long as the world moves along accustomed paths, so long as there are no wild catastrophes, man can find sufficient substance for his life by contemplating surface events, theories, and movements of society." But "when life encounters fiery forces of evil and chaos," he continues, "the man who tries to sustain himself only from the surface aspects of existence will suffer terrible impoverishment, begin to stagger ... then he will feel welling up within himself a burning thirst for that inner substance and vision which transcends the obvious surfaces of existence and remains unaffected by the world's catastrophes" (Weiner, pp. 3–4). In the Jewish mystical tradition of *Kabbala,* one searches for *yesh* in a kind of "subsurface reality," a dimension of existence in which "good and evil [lose] the distinction so apparent to surface vision" (Weiner, pp. 6–7).

Interpreting mysticism

Interpretative approaches to mysticism vary, from those influenced by traditional disciplines such as philology and the history of religions, to those that take their inspiration from contemporary Western sciences of the mind. Frits Staal, for example, canvasses dogmatic approaches, philological and historical approaches, phenomenological and sociological viewpoints, and physiological and psychological frameworks. In this last category, one moves from Freud's dislike for "dark" phenomena such as mysticism and Yoga, to Jung's archetypal metaphysics according to which a variety of mystical phenomena may be classified. Nevertheless, Staal himself claimed that he "would not be surprised if the study of mysticism would one day be regarded as a branch of psychology," by which he meant "that psychology would be deepened and widened so as to be in a position to take account of these particular aspects of the mind" (p. 116).

Psychology and cognitive science. Approaching mysticism from the interpretive lens of cognitive science, visions and locutions offer themselves as interesting candidates for investigation. Neurologist and author Oliver Sacks, for example, frames Hildegard of Bingen in terms of medical literature on migraine. He writes, "The religious literature of all ages is replete with descriptions of 'visions,' in which sublime and ineffable feelings have been accompanied by the experience of radiant luminosity." He continues, "It is impossible to ascertain, in the vast majority of cases, whether the experience represents a hysterical or psychotic ecstasy, the effects of intoxication, or an epileptic or migrainous manifestation" (p. 112). Somewhat similarly, mental health professionals also have investigated patterns of commonality between the reported mystical experiences of religious practitioners and psychotic inpatients, concluding, "Contemplatives and psychotics taken together could be separated from Normals, *but not from each other,* with the Hood Mysticism Scale. The Normals and Contemplatives taken together could be separated from the Pyschotics, *but not from each other,* with the EGO Scale (Knoblauch's Ego Grasping Orientation Inventory) and the NPI (Raskin and Hall's Narcissistic Personality Inventory)" (Stifler, p. 366).

Hindu and particularly Buddhist mysticism assumes "the perfectibility of man," as Herbert Guenther puts it (p. 42). This fact opens the way for some incredible claims concerning human capacities, such as the claims that enlightened humans may attain *ja 'lus,* or "rainbow body," at the time of death, such that their bodies dissolve into rainbow light and all manner of spectacular visions appear to the disciples left behind (Lhalungpa, pp. 82–97). Obviously, traditions postulating no ceiling on human accomplishments open the way for psychological grandiosity to manifest in the character structures of certain practitioners. Invoking a contemporary, psychiatric frame of interpretation, one can recognize a pathological "mechanism of defense" in the "primitive fantasy" of omnipotence (Kernberg, pp. 2–21) and the signs of "narcissistic personality disorder" in fantasies of unlimited success (Beck, p. 234). Along somewhat similar lines, Schumaker argues that we should "understand religion and psychopathology (and, indirectly, hypnosis) as systems of artificial order that are dependent upon an active dissociation process" (p. 34). The fine line between insightful interpretation of one system of thought and practice in terms of the reality framework of another, and critical, almost condescending judgment, on the other hand, however, highlights the difficulties one encounters when employing one specific cultural lens to interpret behaviors arising in different segments of the same culture, or in different cultures altogether.

The status, experience, and understanding of consciousness, awareness, the mind, and the self, occupy tomes of mystical rumination. Indian philosophical systems of thought, and later Tibetan Buddhist writers, excel in this arena. For example, Prabhakara Mimamsaka philosophers occupy themselves with the question of whether or not the self is "self-luminous," concluding, "the self is not consciousness, and while consciousness *(samvit)* is self-luminous, the self is not" (Mahadevan, p. 11). Interestingly, this emphasis on consciousness and awareness makes mysticism a possible ally to contemporary brain science in the West. Mystical accounts from all of the world's major religious traditions, such as the *rnam thar* ("sacred biography") genre expressive of Tibetan Buddhist mysticism, frequently rely upon autobiography and sacred biography (hagiography) as narrative forms, further pointing to the centrality of the "self" and its transformations in the mystical journey. To oversimplify the situation, regular and frequently dramatic personal transformations wrought by the mystical path threaten to destabilize the self, a potentially dangerous, psychological situation mitigated by the creation of a "narrated self" (Wortham, p. 140), which can function as the hero or heroine in tales of miraculous accomplishment, thereby compensating for possible psychological fragmentation by means of a chronological narrative unfolding in which the mystic's own identity remains constant over the course of his or her lifespan.

The role of the body in providing a support for mystical experience constitutes another area in which mysticism and modern science, in this case, medicine, may complement one another. In the medieval Siddha traditions of Hindu alchemy and *hatha yoga,* for example, the body serves as the locus for complex worldly to transcendent transformations, as in when the practitioner utilizes *pranayama* (breath control) to transform mundane semen into the "divine nectar of immortality" and to transform mundane mind into "a state beyond mind" (White, p. 45). Because of its intricate involvement with body, speech, and mind, ritual plays an important role in catalyzing mystical states of awareness, as demonstrated, for example, by the tremendous emphasis placed on ritualized *mantra* repetition in both Hindu and Buddhist mystical traditions (Abe, pp. 138–149). Repetitive, ritualized *mandala* visualization provides a similar, corporeal engagement of the aesthetic sensitivities cultivated by mystical practitioners (Andresen 2000). Perversions of the relationship between self and body, as seen from the perspective of Western medicine's diagnostic recognition of eating disorders such as anorexia nervosa, also has plagued mystics of many traditions. Whitney Miller develops a methodology of "psychomysticism," a kind of "contemplative counseling" in which the counselor emphasizes awareness and sensitivity, "a willingness to pay attention," following Bernard Lonergan's transcendental precept "to 'be attentive'" (p. 1).

The importance of context. Scholars of mysticism continue to debate whether or not mystical experience itself is mediated by context. Constructivists have held the view that, "linguistic, social, historical, and conceptual contextuality" shape the mystic's experience. On the other side, essentialists articulate a position whereby a common, pure core to mystical experiences supposedly exists, not merely within a single tradition such as Christianity or Buddhism, but across cultures and traditions, too. It is possible, as argued by Jensine Andresen, that constructivist and essentialist ("perennialist") positions may be seen to be complementary, inasmuch as species-wide perceptual systems and consciousness, which mediate between the *qualia,* or felt experience of the subjective, and the hard and fast reality of what is conventionally perceived to be an external world, are shared between all members of the human family, mystics included.

See also Experience, Religious: Cognitive and Physiological Aspects; Experience, Religious: Philosophical Aspects; Meditation; Monism; Mystical Experience; Mystics; Neurosciences; Pantheism; Psychology; Spirituality; Transcendence

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JENSINE ANDRESEN

MYSTICS

Mystics are individuals who follow a path towards a final goal or sustained state that is understood as somehow transcending, moving beyond, or more deeply perceiving or intuiting the conventional world of names and forms experienced by ordinary human beings. Prominent mystics, representing various religious traditions, include: eighth century Tibetan mystic Yeshe Tsogyal; Abhinavagupta (tenth century); Muhammed Ibn 'Ali Ibn 'Arabi (1165-1240); Julian of Norwich (1342-1416); St. Birgitta of Sweden (1471-1528); Rabbi Nachman of Brazlav (1772-1816); Ramakrishna (1836-1886); and Thomas Merton (1915-1968). Mystical experience resists easy generalization because of the great variety in personal practices of individual mystics and the marked differences in the broader contextual narratives of individual mystical experiences. Nevertheless, mystics commonly experience unusual states of awareness, utilize poetry and song as vehicles of self-expression, and remind members of societies in which they find themselves, through the attitude of eschewing limits, of the boundaries sometimes imposed by conventional living. At the same time, many mystics recognize their deepest experiences of transcendence within the conventional world, thereby pointing to paradoxes embedded within the mystical life itself.

See also MYSTICAL EXPERIENCE; MYSTICISM

JENSINE ANDRESEN

MYTH

Civilization cannot exist without stories. Every culture in recorded history has created its own narratives to cope with what was fearful, incomprehensible, or uncontrollable, from volcanic eruptions and comets to illnesses and death. These stories, called *myths,* are often, but not exclusively, deeply related to the religious beliefs of a given culture. Myths give order and meaning to the uncertainties of life, whether they are caused by physical or by emotional factors.

Humanity's first attempt to understand nature

Throughout history, different cultures have perceived nature as having a dual role: sometimes the giver of life, the provider of warmth and food, and sometimes the ruthless killer. This was as true to a hunter-gatherer tribe living ten thousand years ago as it is today. In order to appease the unpredictability of nature, it was necessary to somehow interact with it. This was originally achieved through the attribution of god-like status to nature and to the objects of the world that had some relevance to people's lives. In some cultures, Earth itself was a god, the mother goddess, and so were the sun and other celestial objects. Other cultures populated their forests, rivers, and mountains with gods and spirits. Through ritual and sacrifice it was possible to communicate with these gods, and, thus, to plead for their clemency and generosity.

The existence and actions of these many gods, and their interactions with human figures, were told through myths. Thus, mythical narratives translated what was feared and unknown into a language that was readily understandable by people, establishing a bridge between human existence and that which was perceived to be beyond its realm.

The power of a myth is not in its reality but in its persuasiveness. A tragic example is the myth of Aryan supremacy espoused by Nazism, which led to the murdering of Jews, Gypsies, and others during the Second World War. It is a common mistake to interpret a given myth in the light of one's culture and not within its own. The belief system of a Yanonami Indian from the Amazon Basin is quite different from that of a Dutch Calvinist or a Chinese Buddhist. Religious entrenchment, based on specific mythic narratives, often leads to disastrous social and political consequences.

Myths can be understood as humanity's first attempt to interpret and understand natural phenomena. As such, they can legitimately be considered as science's ancestors. In particular, there is an all-pervasive, cross-cultural need to understand the origin of human beings and of the world. These myths, called *creation myths,* are part of every culture, past and present. In the West, the most familiar is that narrated in the biblical book of Genesis, which attributes the origin of the world and of its beings to God. The vast majority of creation myths follow similar lines, in that they credit the existence of the world to the action of a god, goddess, or several gods. These myths fall in a category where time had a specific start in the past, the moment of creation. Still within this category, there are myths that claim the universe originated spontaneously out of chaos, without divine intervention, while others, such as the Maoris of New Zealand, claim it appeared out of nothing. Other creation myths, such as those from the Jains of India, say the universe has always existed and will always exist, while others, like the Hindus, believe the universe is created and destroyed in an eternal succession of cycles.

The transition from myth to science

The same basic concerns with nature and its impact on human existence that are addressed by mythic narratives play a crucial role in the development of science. Questions that were once the exclusive province of religion, such as the origin of the world, the origin of life, and the origin of mind, are now subjects of intensive scientific research. It is possible to trace a gradual, albeit not continuous, transition from the mythic to the scientific discourse. The first rupture with a purely religious description of nature is attributed to the pre-Socratic philosophers, who flourished in Greece during the sixth and fifth centuries B.C.E. For the first time, it is possible to identify an effort to answer questions about nature through natural causation mechanisms, as opposed to supernatural ones.

This tendency continued with Plato and Aristotle, although both included supernatural elements in their schemes of the world. The *Demiurge,* for Plato, was a cosmic intelligence, responsible for the rational design of the world; the *Unmoved Mover,* for Aristotle, was the first cause of motion, the world's primal dynamic impulse. As we move on to the Renaissance and the development of modern science, influences from Greek thought, combined with Christian theology, are clearly present in the works of several natural philosophers, including Johannes Kepler and Isaac Newton. Their task was to translate God's natural creations to humanity, using reason as the common language. The oral and verbal narratives of myths were increasingly substituted by mathematical descriptions of natural phenomena. The very success of the physical sciences served to distance the scientist from the theologian; as humanity learned more about nature through reason, a smaller role was attributed to God and the supernatural in the workings of the world.

Today, science is widely perceived as the antithesis of religion: In a world of reason, there is no place for God and the supernatural. This polarized view of science and religion leads to much confusion. Although it is often argued that there is no place for religion in the modern scientific discourse, it is also true that science cannot completely distance itself from its mythic roots. One of the strengths of science is its universality: A theory or explanation accepted by the scientific community will be correct for every scientist, irrespective of religious creed, nationality, or political stance. However, science comes from individuals who are often motivated by esthetic values. Concepts such as symmetry, harmony, simplicity, order, or mathematical elegance are a major driving force of the scientific creative process. Their origin can be traced back to the need to decode the workings of nature, as was first done through myths.

See also ARISTOTLE; CREATION; GOD OF THE GAPS; HINDUISM; NEWTON, ISAAC; PLATO; SUPERNATURALISM

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MARCELO GLEISER

N

NANOTECHNOLOGY

See BIOTECHNOLOGY

NATURALISM

Naturalism arouses strong emotions. Some see it as a banner to follow, some as the enemy to fight. Theological or religious naturalism is even more controversial: Is it truly religious? And if so, is it still naturalism? However, naturalism is a clear and unified category until one begins to think and read about it. The entry will consider four contexts in which the term arises. Thereafter, some issues in and varieties of theological or religious naturalism will be considered.

Four contexts and contrasts

P. F. Strawson distinguishes in his *Skepticism and Naturalism* (1985) between "soft" and "hard" naturalism. *Soft naturalism* refers to what human beings ordinarily do and believe about, for example, colors, feelings, and moral judgments. When a painting is "naturalist," it is so in a soft sense. *Hard naturalism* refers to attempts to view human behavior in an objective light as events in nature. Strawson argues that these two ways of viewing the world are compatible, but if he has to choose, he opts for soft naturalism. Critics, however, argue that soft naturalism plays down insights about the structures of reality "behind" experience, and thus avoids genuine engagement with the sciences and secular thought. The remainder of this entry deals with forms of hard naturalism, as science not only extends but also corrects the soft natural understanding of reality.

Science is a human practice; its insights may be useful, but why might they be considered true? Cultures with particular social norms survived, but why would one call the intuitions and practices that have evolved good? Can one distinguish truth from mere beliefs, ethics from evolved morality? In this context naturalism stands in contrast to normative views of epistemic or moral values and procedures. Naturalists in this sense tend to deny that any demarcation between science and nonscientific activities, or between moral preferences and ethics, could be absolute. At the same time, however, such naturalists prefer science over pseudoscience and thus live by a distinction between what can be justified and what cannot. Naturalists who seek to ascribe normative standing to science and morality without introducing an absolute realm of values, truths, or procedures, may connect humble origins via a long trajectory across many thresholds to more lofty convictions that, in the end, need not be all too different from traditional ones on ethics and epistemology. For a naturalist, in the sense considered in this paragraph, the transition from description to prescription is never beyond modification, though hopefully approximating the true and good.

In anthropological reflections on the human person as one who acts, thinks, and experiences in this world, naturalism stands primarily in contrast to positions such as rationalism, which are not much interested in the way mental capacities are embodied. Naturalism invites the understanding of humans as materially constituted, owing their abilities to an evolutionary history of billions of years. Within the scientific community and within debates in the philosophy of mind, research projects such as embodied artificial intelligence and connectionism seem to indicate a shift away from the dualistic tendencies of rationalism. The challenge for the naturalist is similar to the one mentioned above: If human beings are nothing but messy natural processes, what can be said of the distinct character of consciousness, ideas, feelings, and the like?

A fourth context where naturalism arises is in contrast to supernaturalism, that is, in relation to theological and metaphysical reflections on transcendence and the ways in which transcendence might manifest itself in ordinary reality. In this context, some consider naturalism to be identical to atheism, but this need not be the case.

Naturalism and natural science

Naturalism often refers to a view of the world that follows the natural sciences as its main guide for understanding the world and human nature. Such a naturalism is not formally implied by the sciences because other logically coherent constructions may be possible, including less restrictive forms of naturalism, such as the one advocated by the Whiteheadian process philosopher David R. Griffin in his *Religion and Scientific Naturalism* (2000).

With respect to ontology, science-inspired naturalism holds that all objects, including human beings, consist of the stuff described by chemists in the periodic table of elements. This stuff is further understood to consist of elementary particles and forces, and beyond that is assumed to consist of quantum fields, superstrings, or whatever. Such a naturalist must grant that human knowledge has not reached rock bottom. Hence, naturalism cannot be articulated from a fundamental ontology upwards. Nor need it imply that all phenomena can be described in terms of physics and chemistry. A conceptual and explanatory nonreductionism may be possible, arguing that higher level properties and entities have their own causal efficacy, just as future entities will be real and causally efficacious even when they are produced by present ones.

With respect to history, naturalism understands living beings, including humans, as the current stage in a bundle of Darwinian evolutionary histories on the planet, which is itself a transient phenomenon in a universe that has been expanding for some fifteen billion years. These insights do not commit one to a particular view on processes near the "beginning of time," if there is one. It is with history as with ontology: Fundamental issues about the beginning of the universe and the nature of time, space, and substance need not be settled for the naturalist.

Naturalism sees social and mental life as one of the fruits of the long evolutionary process. The "understanding" of science and philosophy is one facet of this, even when it reflects upon its own emergence. Naturalism holds that this is not a vicious circularity. Rather, science and other intellectual enterprises can be seen as building upon human capacities for dealing with their environment, improved piecemeal over many generations. Science is seen as a social phenomenon that is cognitively reliable, and increasingly so. Philip Kitcher argues well in *The Advancement of Science* (1993) that the human, historical, and social character of science need not undermine scientific credibility.

The difference between integrity and self-sufficiency

Explanations of facts always assume an explanatory framework of laws and earlier conditions. Conditions and laws can be explained on the basis of other such assumptions. The various sequences of explanations, if pursued persistently, converge via biology and chemistry on the desks of physicists and cosmologists. Their disciplines form a boundary of the natural sciences, where speculative questions with respect to a naturalist view of the world come most explicitly to the forefront. The questions left at the metaphorical "last desk" are questions about the world as a whole, its existence and structure, and not only questions about its beginning. The development of science may change the actual ultimate questions considered at any time. However, naturalism need not imply the dismissal of such limit questions as answerable or meaningless, nor need it imply one particular answer to such limit questions.

Given the lawful integrity of the world as disclosed by the sciences, one may distinguish four views of God's relation to natural reality and its regularities, two of which might be considered naturalistic. These two views are often conflated, to the disadvantage of the religious one. First, a theist might hold that God may act against the laws of nature. Whereas on the basis of natural processes one would expect *a* to happen, God makes *b* occur. Such a view of God's relation to the world has adverse consequences for one's esteem for God's creation (which includes the laws), since created reality is apparently of such a kind that God has to interfere against God's own creation. Second, some authors in the religion and science field argue that there is enough looseness (contingency) in the web God created in the first place to allow for particular divine actions, without going against any laws of nature. This looseness might perhaps be located in complex and chaotic systems or at the quantum level. The natural order could result in a number of different outcomes, say *a, b, c,* and *d,* and God makes it that *c* happens rather than *a, b,* or *d.* This view depends on contingency of an ontological kind *in* nature, whether at the quantum level or elsewhere.

Naturalism need not deny the existence of such contingency in nature; perhaps natural reality is hazy and underdetermined. However, naturalists would in general abstain from supplementing natural reality with supranatural determining factors. Chance is taken as chance and not as divine determination. Naturalism accepts that nature is, when one considers the level of causal interactions, complete, without theologically relevant holes. As created reality, the natural world has an integrity that need not be supplemented within its web of interactions. However, this integrity is not to be confused with self-sufficiency; it does not imply that natural reality owes its existence to itself or is self-explanatory. Thus, it is important to distinguish between naturalism as emphasizing the integrity of the natural world (the third view), and naturalism as claiming also the self-sufficiency of the natural world (the fourth view).

Arguments about the self-sufficiency of reality need to be different from arguments about explanations within reality. This difference is often neglected in atheistic arguments that appeal to science, such as Peter Atkins in *The Creation* (1981), in which he claims that science is about to explain everything. He traces back everything to a beginning of utmost simplicity, but he cannot do so without assuming real existence and a framework wherein certain rules and mathematics apply. A naturalist need not assume the self-sufficiency of the framework when seeing the framework itself as a whole that has integrity.

Transcendence: some naturalistic options

A naturalist who appreciates the integrity and lawfulness of reality can still conceive of a creator of this framework, the ground of its existence. This is best understood as a nontemporal notion. When God is not seen as one who interferes, the alternative is not to see God as the creator who started it all a long time ago but rather to think of God as the one who gives all moments and places of reality their existence and order. In such a way, one can combine a naturalist view of reality with theistic dualism, understanding the natural world as a whole as creation, dependent upon a transcendent creator. This might be articulated with the help of a distinction between primary and secondary causality, or between temporal processes in the world and timeless dependence of the temporally extended world on God. Such a view emphasizes, as do the monotheistic traditions, the distinction between God and everything that is not God.

The ontological dualism characteristic of such a naturalistic-theistic position is unattractive to many naturalists, who are concerned that any reference to a creator or ground introduces a supernaturalism that diminishes the integrity of the natural. Such naturalists might be attracted to a pantheist view, denying ontological duality of the natural and the divine; the natural is in some sense the divine. Traditional attributes of the divine, such as atemporality and omnipresence, can be associated with the laws of nature, which are upon this view not so much rooted in a transcendent source but immanent in natural reality. Reality may be *causa sui* in that quantum theories may allow a temporal universe to emerge, and at a smaller scale self-organization is characteristic of many processes. However, as in the preceding case, pantheistic answers are invoking further questions and objections, just as the theistic answer always allows for the further question about why such a god would exist.

A third option is an agnostic stance. Milton Munitz defends in his *Cosmic Understanding* (1986) that any actual theory of the universe is conceptually bounded; there might be a dimension of reality "beyond" any such account, but it could not be expressed adequately in language. "We shall be driven, consequently, and at the end, to silence, although the 'talk' on the way, if at all helpful, will have had its value in making the silence a pregnant one, and indeed an occasion for having an overridingly important type of human experience" (p. 231). Similarly, in his *In Face of Mystery* (1993), the theologian Gordon Kaufman points out various problems with the dualistic language of theism, as if we on this side of the great divide can know that which is on the other side; our knowledge of the world in which we live "always shades off into ultimate mystery, into an ultimate unknowing" (p. 326). Emphasizing "mystery," not-knowing is a safe strategy. However, it does not offer much guidance as to particular choices to be made in life; the notion of mystery is more epistemic than axiological or ontological.

These different theological views—the theist, the pantheist, and the mysterianist—are all generally compatible with a science-inspired naturalist understanding of reality. The way they are articulated and defended may be influenced by current scientific theories, but variants of these positions can be formulated again and again.

A different naturalistic challenge: religion as a phenomenon

Science-inspired naturalism is a challenge for religion since it presents a view of the world that differs from traditional religious images. This leads in religion and science to conflicts between science and religiously motivated beliefs, such as creationism. However, a naturalist view also considers religions as phenomena within reality. Thus, they can be studied just like other human practices. The neurosciences may inform us of aspects of our constitution that give rise to our "inner life." And in an evolutionary perspective most naturalists would explain the emergence of religions functionally along lines similar to explanations for political institutions, languages, and other social phenomena: Religions arose because they contributed to the inclusive fitness of individuals or communities in which they arose and which in turn were shaped by them. An alternative could be that religions arose as a side effect with the emergence of some other trait, such as the rise of consciousness. Thus, naturalists might see religions with their myths and rituals as valuable means of dealing with the challenges of life. However, a contested issue then becomes whether we should take the vehicles (the rituals, myths, narratives, conceptualities, etc) seriously as cognitive claims, or whether those who want to take the cognitive claims seriously should reject the functional naturalistic approach.

Religious naturalism as thick naturalism

Religious naturalism might be understood as a "thick" naturalism, with idiosyncratic elements that allow for a decent amount of coping with the vicissitudes of life, with stories that support values and motivate humans. The notion "thick" is appropriated here from a distinction made by the anthropologist Clifford Geertz between thin and thick descriptions of a culture. Whereas the one offers a fairly abstract and general (thin) description, the other concentrates on the multitude of habits, beliefs, skills, narratives, and the like, which make for a more tightly woven whole.

For the history of religious naturalism one might refer to philosophers, scientists, and theologians of various backgrounds, including Henry Nelson Wieman, George Santayana, John Dewey, Charles Sanders Peirce, Ralph Burhoe, Mordecai Kaplan, and Jack J. Cohen, and to some extent even Alfred North Whitehead and William James (there is a huge overlap between religious naturalism and American pragmatism). Beyond the last century and a half, one may go back further in time and claim to be heirs of Spinoza as well as of other pantheistic scientists. Claiming these as ancestors is to some extent appropriation out of context, but that is precisely the intellectually ambivalent practice that strengthens identity. These "ancestors" were all perceived as somewhat heretical in their times, while standing in close contact with, if not being part of, the scientific community—precisely the mix that may fit contemporary religious naturalism.

Like any subculture, religious naturalism is not uniform. To the contrary, as in any living community there have arisen dialects, with different speakers giving their own interpretations to the words. There are Christian and humanist dialects of religious naturalism, as well as biological, psychological, and physicalist ones, all of which reflect upbringing, training, and heritage, as well as needs and situations. Some dialects are dialects of another tradition as well, just as the local dialect near the border of the Netherlands is considered by some to be a dialect of Dutch, whereas others treat it as a dialect of German. Thus, liberal or revisionist forms of theology may be read as forms of Christianity, as well as of religious naturalism. There is a wide range of personal styles, from the sober, minimalist, and analytical (e.g., Jerome Stone, Charley Hardwick) to the evocative (e.g., Ursula Goodenough). Religious naturalism has become an umbrella that covers a variety of dialects, of which some are revisionary articulations of existing traditions, whereas others may be more purely naturalistic religions indebted almost exclusively to the sciences. There are family resemblances, with affinities and disagreements, but not unity.

See also SUPERNATURALISM

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WILLEM B. DREES

NATURALISTIC FALLACY

The relation between is/ought, fact/value, objectivity/normativity, and science/ethics all touch on the notion of the naturalistic fallacy. In general terms, this notion is an expression of the philosophical argument that one cannot infer from the one to the other; one cannot infer from *is* to *ought,* nor can one make an inference from scientific observations to ethical arguments. Any such attempt means committing the naturalistic fallacy. Historically, David Hume (1711–1776) and G. E. Moore (1873–1958) were the primary advocates of the invalidity of a moral argument based on such an inference.

In *A Treatise of Human Nature* (1740) David Hume argued that morals cannot be derived from reason. Rather, feelings should be considered the proper basis of morals. Reason can not account for the passions and affections that arise in questions of morals, but only the questions of objectivity (i.e. truth and falsehood). What *is* cannot serve as a basis of what *ought* to be. One cannot derive the moral *ought* from the objective *is.*

The term *naturalistic fallacy* goes back to G. E. Moore, who in *Principia Ethica* (1903) argued that the notion of the good could not be based by reference to nonmoral entities. The good is a simple, indefinable concept, not composed by other nonmoral parts. This is precisely the problem of the naturalistic fallacy, which points to nature or to some other nonmoral entity and argues that this serves as the basis of moral normativity. Thereby the difference between these parts is ignored, as is the invalidity of inferring from one to the other. By committing the naturalistic fallacy, one would substitute "good" with a nonmoral property.

The ideas of Hume and Moore have had important consequences for the debate on the relation between science and ethics. If Hume and Moore are right, it is not possible to derive normative precepts from scientific observations. Objective findings have no bearing on the question of what one ought to do. The theory of evolution has no implication for ethics. The scientific understanding of human nature is not relevant to the normative understanding of human nature. *Is* and *ought* are two separate entities that are to be kept separate if one wants to establish a proper philosophical normative statement.

In a contemporary setting it is debatable whether the inference from *is* to *ought* is a fallacy. In various theories of environmental ethics, for example, it is stressed that one cannot isolate *ought* from *is.* Holmes Rolston argues that nature holds objective values, and it is necessary for ethical reflection not to ignore this fact. However, the human being's character as a valuer also implies the necessary reflection on these values. In this sense, there is a necessary inference from *is* to *ought.* J. Baird Callicott takes a similar stance, even if he does not stress the necessity of the reflective powers of the human being. Morality arises from the membership of human beings in the biotic community. Apart from these theories of environmental ethics, the necessary inference from *is* to *ought* is also found in most ethical theories based upon notions of evolution and the relation between the concept of nature and ethics. Therefore, the question of the justifiability of the critique of the naturalistic fallacy stands open.

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NATURALIZED EPISTEMOLOGY

Traditionally, epistemology was conceived as first philosophy, that is, as an autonomous and purely normative (*a priori*) discipline that lays down universal criteria of knowledge, truth, and justification. According to this influential tradition, knowledge is justified true belief, and a belief is justified if it is properly basic, that is, self-evident or evident to the senses, or if it is derived from such a belief, whether deductively, inductively, or abductively.

The rise of naturalized epistemology began in the 1950s and 1960s when logical positivists, such as Rudolf Carnap (1891–1970) and Hans Reichenbach (1891-1953), and critical rationalists, such as Karl Popper (1902–1994), still advocated the view that the theory of scientific knowledge should be purely normative, strictly confined to contexts of justification and to the logical aspects of scientific discovery. Referring to the work of Michael Polanyi (1891–1976), Norwood Russell Hanson (1924–1967), and Thomas Kuhn (1922–1996) in dislodging epistemology from its status as first philosophy, W. V. O. Quine (1908–2000) introduced the term *epistemology naturalized.* He suggested that the epistemological enterprise had better be conceived in terms of interplay between normative and empirical concerns. As the latter are relevant to the former this means that, on the one hand, epistemology now ought to make full use of the findings of biology, (cognitive) psychology, sociology, and linguistics when dealing with issues of perception, memory, reasoning, belief formation, knowledge acquisition, and the like. On the other hand, epistemology may go on dealing with the normative aspects of these issues whether in the guise of logical reconstruction or conceptual analysis, or both. Precisely how the balance between structure and genesis should be struck is a matter of ongoing dispute. All naturalizing epistemologists are empiricists, but some take epistemology as a branch of descriptive science (D. T. Campbell) while others uphold its normativity as part of a multidisciplinary endeavor (Alvin I. Goldman).

An early example of naturalized epistemology is the genetic epistemology of the French psychologist Jean Piaget (1896–1980), who in cooperation with logicians such as Evert Willem Beth (1908–1964) and Leo Apostel (1925–1995) did much to undermine the gap between structure and genesis of knowledge. Other examples are Polanyi's theory of tacit knowledge and Popper's evolutionary epistemology, though the latter's rationalist ideal of objective knowledge without a knowing subject appears to counter its naturalism. Further examples of sophisticated naturalist epistemologies are Goldman's epistemics, the Austrian biologist Franz M. Wuketits's evolutionary epistemology, and Alvin Plantinga's reformed epistemology.

In regard to science and religion, naturalizing religious epistemology would mean fully employing the resources of the natural sciences, including evolutionary biology, paleoanthropology, and sociobiology, in accounting for the experiential and cognitive aspects of religious life. This can be done in more or less radical ways—for example, as part of a radical naturalistic program in philosophy that has no place for transcendence, whether supernatural or not. Or, in an equally radical way it might be done as part of a theistic program with a naturalistic epistemology as a subsidiary. In a more modest way it might be done as part of an empirical theology that takes inner worldly experiences of transcendence seriously, whether in the life of modern human beings or in the traces left by the earliest human ancestors.

See also EPISTEMOLOGY; EVOLUTIONARY EPISTEMOLOGY

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NATURAL LAW THEORY

Natural law is the understanding of a moral law that is either given with nature and known through reason or given with moral reason independently of nature. Natural law is universal and common to all humanity. It transcends differences in culture, religion, and various formulations of moral law. It is often understood as the fundamental source of normativity from which positively formulated moral norms must be derived if morally justifiable. As the counterpoint to positive laws, natural law is the criterion of justification for political and biblical law.

Historical overview

The notion of natural law can be traced to the stoic understanding of the common law (Greek: *nomos koinos*), which permeates being and constitutes a cosmopolis in which the human being as a rational being participates. On the basis of a monistic metaphysics, the Stoics argued that there was a similarity between the law of the universe and the law of reason. The right action is that which is in accordance with nature, the cosmic law of reason. The influence from the Stoics was quite clear in the works of early Christian leader Augustine of Hippo and especially the medieval philosopher Thomas Aquinas. Aquinas argued in *Summa Theologica* that "the participation of the eternal law by rational creatures is called the law of nature" (I, II, 91, 2). Natural law (lex naturalis) was understood as a reflection in reason of the eternal law (lex aeterna), which was the constitutive law of being. As an eternal law it was a metaphysical explanation of divine reason. Divine reason was the source of the perfect order of being. Due to the Aristotelian influence, Aquinas also argued that the natural world would strive for its perfection, which ultimately was defined according to the eternal law. In natural law this good was reflected as a natural good, the basic reason why natural beings would strive for perfection.

This close link between physical nature and natural law as a law of reason became increasingly problematic, even if one still finds many advocates of this view. For Protestant reformers natural law is often endorsed as a law of reason because the depravity of nature makes it impossible to let nature serve as the basis of moral normativity. Thomas Hobbes, the seventeenth-century English political theorist and philosopher, further lessened the link between nature and reason. Hobbes developed an understanding of natural law on the basis of a contractarian scheme of thought, where natural law was to be conceived of as articles of peace decided upon by the parties of the contract. The contractarian basis of natural law thought furthered the dissolution of the close link between nature and reason as the basis of natural law. By the time of the Enlightenment, natural law had become a law of reason. The German philosopher Immanuel Kant is the leading proponent of this understanding of natural law. In his major work, *The Metaphysics of Morals* (1797), Kant made extensive use of natural law thought, but natural law in a normative sense was now understood as a law of reason.

Contemporary reformulations

In a contemporary setting various attempts are made to reformulate the notion of natural law. If one could point to a common feature for most of these attempts, it would be a tendency to move beyond a metaphysical basis of natural law. Most can also be seen in the light of the impious hypothesis of seventeenth-century Dutch statesman Hugo Grotius: the endorsement that the normativity of natural law is valid, even if God does not exist. However, this does not necessitate a rejection of the existence of God. It merely stresses the independent normative basis of natural law.

The best known attempts at reformulation have their roots within a Thomistic tradition. The works of John Finnis and Germain Grisez during the 1980s have been the most influential from this train of thought. The common feature for Grisez and Finnis is an attempt to develop a normative moral theory based on a notion of basic human goods. Certain goods, such as life, knowledge, play, aesthetic experience, and religion, are derived from human nature. Moral life is to further these goods. Jean Porter argues in *Natural and Divine Law* (1999) that the normativity of nature can be endorsed in a contemporary setting on the basis of an evolutionistic explanation of the genesis of morality. Furthermore, metaethical naturalism also supports such a reformulation. The normative concept of nature is, therefore, quite plausible in a contemporary setting. Apart from the Thomistic reformulations of natural law one also finds a few attempts of reformulation within a Protestant tradition by, for example Ian Ramsey and David Little.

In addition to these theories with a religious basis, one may also point to various theories of moral philosophy, which may be seen as contributing to the reformulation of natural law. If one is only concerned with explicit natural law thought, the philosophical attempts at reformulation are relatively few. However, if one takes more indirect uses of natural law thought into consideration, one can find various attempts to reformulate the idea of natural law in either a more rational or naturalistic sense. In the more rational sense, one can point to the political theory of John Rawls. Rawls's theory of political justice, which is based upon the contractual agreement of parties may be seen as a theory where the notion of reason holds a normative implication in the constructive sense. The Kantian influence in this theory is evident in the focus on reason as the source of normativity. More naturalistic reformulations include, for example, Holmes Rolston's theories of environmental ethics. Rolston argues that values are given in nature, moral values are independent of the moral valuer, and nature is the source of moral values. This applies to human as well as nonhuman nature. Every natural organism has a natural good that serves as the source of the moral good. The moral good is defined as being in accordance with nature. The theories of Rawls and Rolston are both examples of theories where the primary attempt is not to reformulate natural law theory. Both of these theories, however, demonstrate important similarities to this classical concept.

See also KANT, IMMANUEL; NATURAL THEOLOGY; THOMAS AQUINAS; VALUE, RELIGIOUS

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NATURAL SELECTION

See EVOLUTION, BIOLOGICAL; SELECTION. LEVELS OF

NATURAL THEOLOGY

Natural theology is the part of theology that does not depend upon revelation. During the Middle Ages, natural theology included arguments for the existence and nature of God, for the immortality of the soul, and for the basic principles of morality insofar as they are founded on nature as created by God.

The first flourishing of natural theology was in ancient Greece. Plato's dialogue, the *Phaedo,* contains a number of weak arguments for the everlastingness of the soul, and Aristotle's *Metaphysics* contains arguments for a "Prime Mover," which is also the best of all possible beings. In the Christian tradition, medieval theologians, often appealing to Romans 1:18–20, developed the viewed that natural theology could establish the existence of God, which it is logically necessary to do before discussing the things that God had revealed. The first Vatican Council, held from 1869 to 1870, defined as a matter of faith that the existence of God could be demonstrated by reason. The best known arguments in this regard are those of medieval philosopher and theologian Thomas Aquinas, whose "Five Ways" for demonstrating God are drawn from Aristotle.

Aristotle's four causes

In Aristotle's (384–322 B.C.E.) work, there is no sharp distinction between physics and theology. The Prime Mover is part of a scientific explanation of the universe, which explains why and for what purpose the universe exists. Aristotle describes four basic types of causes, and a complete causal explanation would trace them to an ultimate self-evident origin. There must be an ultimate efficient cause of the universe, something that brings everything else into being without itself being capable of entering into being or of passing away (it will be eternal). It will cause changes without being capable of change (it will be immutable). It will generate all transient things without itself being affected by anything (it will be necessary). According to Aristotle, there must be an ultimate formal cause of the universe—something that includes the natures of all things in a higher and underived manner (it will contain all possible perfections). There must be an ultimate final cause of the universe—something to which all things strive, or for the sake of which they exist (a perfection that all things strive to imitate in their own way). And there must be an ultimate material cause of the universe—something out of which it is made, which is not itself made out of anything more basic.

For Aristotle, the eternal, immutable, necessary, perfect pattern of the universe is one and the same being, since an all-perfect being will be eternal, immutable, and necessary. Prime matter, however, the material cause, is in itself imperfect and formless, and is a basic brute fact alongside the perfect being. Aquinas (c. 1225–1274) adopted all these arguments, and agreed with Aristotle that the efficient, formal, and final cause of the universe is not its material cause. But he argued that matter is not an ultimate principle. It is brought into being "*ex nihilo*" by the cause of the universe which is wholly immaterial and which, he said, "all men call God" (*Summa Contra Gentiles* 1, 13).

These arguments for God are essentially arguments to an ultimate cause, which will provide an ultimate explanation for the universe. Perhaps the "first cause" simply exists, as the ultimate brute fact. But one might push the argument as far as it can go, and say that the first cause has to exist. It cannot fail to exist, since it is the very source of all possibilities, and without it nothing would be even possible. The twentieth-century philosopher Richard Swinburne calls this an "absolute explanation," since it arrives at a being that is self-explanatory, whereas an ultimate explanation simply arrives at a being that cannot be explained in simpler or more basic terms.

These arguments continue to be the basis for most arguments in natural theology, construed as an attempt to explain the universe, but they have ceased to be considered a part of science. This is largely because science has rejected Aristotelian forms of explanation as being both superfluous and vacuous. Aristotelian science looked for the "essences" or true natures of things, and assumed that the essences must be brought about by things which were like them and at least as "great" in reality, and that each thing must have a "final cause" or purpose for the sake of which it exists.

Since the sixteenth century, scientists have ceased to look for "real essences" or for "final causes," and have given up the causal principle that things must be brought into being by other things that are like but greater than themselves. Such investigations led to no practical results. Instead, the "new scientific method" consisted of close observation, repeated experiment, and the formulation of general precise laws that govern events. Using this new method, one discovers no real essences, final causes, or efficient causes in the sense of beings that "bring about" their effects by some inner propensity. What one finds are sets of general laws and regular principles that are effective in describing and predicting series of events.

"Explanation" becomes the formulation of such laws, and an ultimate explanation would consist in the formulation of a general law that cannot be subsumed under a higher, more general, or simpler law. The idea of a First Cause, in the sense of a perfect and causally efficacious being, has disappeared from science. Science still asks why the ultimate laws of nature exist, but a scientific answer is likely to lie in a demonstration that such laws exist by some sort of inherent necessity. The eternal and perfect originator of the universe of Aquinas has been transformed by science into the inherent necessity of an ultimate mathematical formula, which is not "what all men call God."

Experimental sciences and idealism

Natural theology thus lost its scientific credibility with the rise of the properly experimental sciences. For some, however, this merely indicated that the natural sciences had limited the range of their enquiries to phenomena that could be measured, repeatedly observed, and explained under general mathematical laws. Questions about the ultimate nature, origin, and destiny of the universe remain, and if science does not attempt to answer such questions, then metaphysics or "first philosophy" must try.

As a result, a second stage in the history of natural theology began in seventeenth-century Europe with the rise of philosophical Idealism—the view that the ultimate nature of the universe is spiritual, that physical phenomena are appearances of that spiritual realm, and that the intellect can uncover the structure of the spiritual world, with which the physical sciences cannot deal. It is characteristic of this approach that it seeks to take conscious experience as its fundamental clue to the nature of reality, and to explain physical phenomena as confused appearances of basically conscious entities, or perhaps of one supreme Spirit.

The Idealist approach raises in an acute way the question of the relationship between the sciences and the humanities, or between physical and mental states. It may be claimed that law-like explanation which is open to any detached observer is only appropriate to physical phenomena, whereas one must understand the phenomena of consciousness in terms of interpretation, empathetic understanding, and personal engagement. Whether such a broad difference between human and natural sciences exists and is irreducible, is strongly disputed.

Rationalist or Idealist philosophers seldom agree with one another, and there seems to be no way of objectively verifying their claims. However, this is to be expected from systems that claim to be based on personal engagement and interpretation. The difference between traditional natural theology and Idealist natural theology is clearly exemplified in the writings of German philosopher Immanuel Kant (1724–1804). Kant is best known for his destructive criticism of the traditional arguments for God, but he firmly believed that there is an underlying reality that is the cause of physical reality as it appears to our senses. According to Kant there can be no theoretical knowledge of such reality in-itself (what he termed "noumenal" reality), but the mind does provide a priori knowledge of the form and order of sensory appearances (so knowledge does not depend merely on empirical information). Knowledge depends on the inner structure of reason, and reason necessarily postulates God, freedom, and immortality as ideas in terms of which we must represent ultimate reality to ourselves.

Kant is also, as are most idealists, firmly committed to science understood as the investigation of the rational structure of phenomenal experience. The claim would be that idealism—i.e., the postulate that the universe must be thought of as basically mind-like—is the surest foundation of the natural sciences, which must presume there is a rational structure in the natural world. But Idealism also points out that there are limits to science, which are reached when it claims to disclose the ultimate structure of reality, or to extend its reach into the realm of the personal or spiritual. That is a realm into which philosophy can reach, with the aid of its principles of rational coherence, establishing a system within which consciousness, value, and purpose can have an intelligible place. The crucial question is whether the concepts of value and purpose have a place in explanations of the universe. If they do, then an Idealist approach offers a complement to science, which only comes into conflict with it if and insofar as value and purpose are denied.

Modern appropriations of the design argument

The failure to establish useful general laws in psychology and sociology, as well as the subjective nature of much of history and economics, suggests that these areas are not amenable to the scientific techniques that have been so useful in physics and chemistry. But the fields of neurophysiology and of evolutionary psychology contain promises (or threats) to explain consciousness itself in physical or evolutionary terms. Consciousness may be a byproduct of past successful survival strategies, and its present functioning may be incidental to the adaptive functions (of discerning prey or avoiding predators) that it originally possessed. This sort of natural theology, which argues from consciousness to a supreme consciousness or Spirit, needs to argue that consciousness is an irreducible and distinctive phenomenon beyond the reach of experimental science. That remains a highly disputed issue.

A third, slightly different approach to natural theology reverts to the methodology of the sciences, not the Aristotelian method of searching for essential natures, but the experimental method of inferring hypotheses from observed evidence. The most famous example of this approach is found in the work of eighteenth-century English theologian William Paley, who inferred from evidences of design in nature the existence of a wise designer. This approach is unlike the Aristotelian approach, since it does not assume that all substances have final causes. Rather, Paley's approach looks at organisms, in particular, as highly organized and efficient systems for supporting animal and human life, and argues that it is much more probable that such systems are designed than that they originated by chance. If we found a watch, says Paley, we would surely infer that it had a designer, it is so intricately organized to a purpose, with all its parts finely balanced and tuned to one another. So we must infer that the world has a designer, for similar reasons.

This approach was dealt a severe blow by Charles Darwin's (1809–1882) theory of evolution and natural selection, which claims to show how well-designed organisms can evolve, if not by chance, than at least by random mutation and natural adaptation to the environment, in strongly competitive situations. Given the difficulty Paley has in accounting for why such strange organisms as giraffes and ichneuman flies (which lay their eggs in living caterpillars) exist, mutation and natural selection seem a better explanation than trying to figure out why God would design such odd or unpleasant creatures.

Nevertheless, design proponents argue that a wise creator may not have specifically designed every type of creature that exists. But such a creator might have designed the general laws of genetic mutation and environmental selection so that they would generate sentient rational organisms by a process that is partly random, yet directed to certain goals (the existence of rational agency). When one adds to this the extreme improbability of the laws of nature giving rise to a universe with life-forms in it at all, one has an argument to the general elegant design of the laws of nature and of evolution, if not to all their particular products. Many of the findings of physics, which disclose the elegance and integrated simplicity of the fundamental forces of the physical world, and those of biology, which reveal the amazingly complex structure of DNA and the adaptedness of living creatures to their environment, are strongly suggestive of design.

On the other hand, some argue that any universe with conscious beings in it would have to be complex and ordered in just such a way, so it is hardly surprising that we find such complex order. The structure is highly improbable, but so is the existence of any universe at all, so this universe is no more improbable than any other. In addition, it may be doubted whether it makes sense to speak of purpose or direction in evolution, and whether existence is worthwhile at all. So these probabilistic arguments of design-type natural theology are far from conclusive.

It seems that the universe, as science shows it to be, could be the work of an intelligent creator. But the universe may also just happen to exist as it does. The inference to a creator is not strictly required. The arguments of natural theology may seem to make a creator probable to many people. They do show the intelligibility and elegance of the universe, and thus enrich the idea of a creator that a theist might hold. But they are not overwhelming, and non-scientific factors concerning the value and possible purpose of creation will probably weigh the balance one way or another.

Contemporary assessment

Partly for this reason, many theologians deny that religious belief depends upon the success of natural theology. Some, like Swiss theologian Karl Barth (1886–1996), even argue that the program of natural theology is based on human arrogance, and flies in the face of revelation, which is to be accepted on faith, not because it seems on balance to be probable. Kant said, "I have had to deny knowledge, in order to make room for faith" (p. 29). He meant that only when it could be shown that no speculative knowledge of transcendent reality is possible, so that one could neither affirm nor deny God by argument, was one free to adopt faith on practical or moral grounds.

It has come to be widely held in modern theology that faith results either from a commitment of the will (Søren Kierkegaard [1813–1855]), or from some basic and nonrational apprehension of the holy (Friedrich Schleiermacher [1768–1834] and Rudolf Otto [1869–1937]), or, as according to John Barth, simply from an act of divine grace, which has no rational grounds. The problem with such views is that they prevent anyone from giving a reason why they should adopt one faith (say the Christian) rather than another (Islam, perhaps). Such views are also in danger of isolating religious belief from scientific belief, so that religion and science have no relation to one another. Yet it seems odd to say that religious belief in a creator God is not affected by new discoveries about the nature of the created universe, or that religious beliefs (such as the belief that God is one rational purposive creator) have nothing to say about the nature of such a creation.

Natural theology is often no longer seen as the task of proving that God exists, or of showing to any independent observer that God is the most probable explanation of why the universe is the way it is. But, it might be said, one should be able to assemble the best human knowledge in all the diverse areas of human activity, and show how it can reasonably be construed, and even shaped into a more coherent form, by the insights of religion, which may themselves derive from some distinctive source in revelation or experience. Natural theology will then be the attempt to show how science, history, morality, and the arts are so related that a total integrating vision of the place of humanity in the universe may be formulated. Such a vision will be religious insofar as it includes reference to an encompassing reality that is transcendent in power and value, and that may disclose itself in distinctive ways. This will not be proof, or even probability, starting from some neutral, completely shared ground. It will be an integrating activity of reason, both provisional in its formulations and constructed from a standpoint of specific basic postulates and personal value commitments. Within such a perspective, science will be able to make a positive contribution to natural theology, and natural theology will develop ways of integrating scientific activity into a wider worldview. This will be more of an imaginative art than an inferential or deductive science. It will not be the intellectual foundation or prelude for faith, but will involve the construction of a general worldview within which faith can have an intelligible place. That is not too far from the aims of Aristotle, though the distinctions between natural science, philosophy, and religious belief are now clearer (but only in some ways) than they were for him. In this form, natural theology becomes the speculative and constructive part of the post-eighteenth-century discipline of the "philosophy of religion." As such, it is not confined to one particular religious tradition, and its exponents may hold any or no religious beliefs.

However, there are many philosophers of religion who would hold that systematic construction is not properly part of philosophy, the function of which should be primarily analytic and expository. Therefore, natural theology in all its form remains, like religion itself, a highly pluralistic and disputed discipline. It is clear, however, that this is an area in which science and religion fruitfully interact in examining the fundamental problem of the ultimate nature of existence.

See also ARISTOTLE; DARWIN, CHARLES; DESIGN ARGUMENT; EVOLUTIONARY PSYCHOLOGY; IDEALISM; KANT, IMMANUEL; RATIONALISM; THOMAS AQUINAS

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KEITH WARD

NATURE

Nature refers to the source out of which something has come into being. The word *nature* is derived from the Latin *natura* (birth) or *nasci* (to be born). A similar meaning is found in the Greek *physis,* which means growth. The concept of nature holds a variety of meanings, depending on the relation in which it is understood. In a political setting, nature is often seen in contrast to custom, culture, and law. In religious terms, nature is often opposed to grace and spirit. Viewed philosophically, nature can be understood in contrast to history and freedom. Nature can also be seen as: (1) the object of scientific observation and enquiry; (2) a normative notion, such as the question of "natural" behavior; (3) an essential notion, such as human "nature"; and (4) a notion concerning evidence, as in the exclamation "naturally!" These different meanings can be taken either as a sign of the philosophically problematic use of this notion or its need of specification.

Historical overview

Several of these concepts have their roots in ancient Greek philosophy. In pre-Socratic philosophy nature was seen in contrast to relativism. Cultures varied, but nature was considered constant and was therefore regarded as ethically normative. Aristotle, who understood nature in teleological terms, carried the notion of the normativity even further. The essence (form) of natural beings carried with it a certain purpose that determined the good life. The morally good life was believed to be in accordance with nature, an understanding further developed in Stoic philosophy, which argued for life in accordance with nature.

These concepts of nature had an enduring impact on theological and philosophical thought during the Middle Ages. During this period, however, a contrast between nature and the supernatural was increasingly endorsed. Nature was distinguished from the divine. For the Christian philosopher Thomas Aquinas (c. 1225–1274), however, nature was not opposed to the divine. Aquinas maintained an analogy of being (*analogia entis*) between eternal law (*lex aeterna*), the constitutive law of being that is identical to divine reason, and natural law (*lex naturalis*), which is understood as the participation of the rational being in eternal law.

During the sixteenth century, nature could also be set in contrast to divine will. Consequently, in the beginning of the seventeenth century, nature became increasingly understood as morally neutral. As physics became identified with mechanics during the scientific revolution, nature came to be understood in mechanistic terms, as something that could be described with physical laws. This change in the role of the sciences, and the corresponding change in the understanding of nature, implied a different relation to nature. Nature became understood as that which was different from human beings and that which humans, as rational beings, were to control. The natural sciences served this purpose as knowledge about nature was regarded as power over nature.

The philosopher Immanuel Kant (1724–1804) had an enduring impact on the scientific understanding of nature. According to Kant, the different objects of nature could not be known in themselves, but could only be known as appearances determined by the epistemological categories of space and time. Consequently, Kant's transcendental philosophy implied that in the apprehension of nature human beings were structuring the very same nature. Kant became influential for his emphasis on the interrelation between nature as an object and the formative impact of the human apprehension of nature.

Another fundamental turn in the scientific understanding of nature was the publication of Charles Darwin's *On the Origin of Species* (1859). According to Darwin's theory of evolution, new species originated from other species, and natural life was formed according to the principles of variation and natural selection. This view of nature has often been seen as opposed to a theological understanding of nature as designed by God. As a consequence, nature was no longer considered as good in itself, but as morally ambiguous.

Modern scientific concepts of nature

In a contemporary setting, the diversity of the notions of nature is as varied as in previous epochs, with a host of holistic, religious, and ecological understandings in play. Karen Gloy has demonstrated how an organicist notion of nature has been in use since the Renaissance. The ecological mode is present in environmental ethics. The philosopher J. Baird Callicott argues that nature is to be seen as a biotic community. Based on evolutionary theory, nature is regarded as an interrelated, interdependent, ecological web of life, which raises the ethical implication that the good is defined as that which furthers the stability of the biotic community. Jürgen Moltmann endorses a theological understanding of evolution in which evolutionary theory is not contrary to the doctrine of creation. Like Callicott, Moltmann argues that the ecological community of life serves as the basis of the moral demand to preserve nature. Furthermore, both Callicott and Moltmann endorse the connection between a holistic and normative notion of nature.

In other theories, nature is seen as self-organizing. Niels Henrik Gregersen views nature in the light of autopoietic systems theory. It is argued that the Christian theology of creation is not contrary to an understanding of nature as self-productive. God's self-consistency and self-relativization in exchange with nature is endorsed. God not only sustains nature but is also seen as a structuring cause. Michael Welker challenges the traditional concept of creation. Often creation is understood as a unique act of bringing into existence, but Welker argues that God is not simply active but also reactive in the creation of the world. The act of creation is an interaction between God and the activity and productivity of nature. Both Gregersen and Welker argue for the self-productivity of nature.

Nature continues to be a fundamental religious, philosophical, and scientific concept. The variety of meanings and aspects to this notion is perhaps one source of its continuing appeal to various discourses of enquiry.

See also AUTOPOIESIS; KANT, IMMANUEL

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ULRIK B. NISSEN

NATURE VERSUS NURTURE

Nature and culture are classical opposites, or complements. By nature we are "born that way"; by nurture we learn to become civilized.

In one sense, "nature" refers to everything generated or produced. Etymologically, the Latin *natura* is the source from which all springs forth. For metaphysical naturalists, perhaps also for methodological scientists, nature is all that there is, without contrast class. Nothing non-natural or supernatural exists. Humans evolved within nature and break no natural laws. Another view holds that a straightforward contrast class for nature is culture, which nurtures humans into an inherited linguistic and symbolic system, a worldview, by which they communicate, perpetuate, and develop knowledge. This cultural genius makes possible the deliberate and cumulative, and therefore the extensive, rebuilding of nature. Humans reshape their environments, rather than being themselves morphologically and genetically reshaped to fit their changing environments. Humans come into the world by nature unfinished and become what they become by nurture.

Cultural education

Etymologically, "culture" is related to "cultivate," while "nurture" is related to "nurse" and "nourish," with overtones of rearing and training. Religious persons find their traditions vital in such nurture, and absent from nature. "Train up a child in the way in which he should go" (Prov. 22:6).

Such cultural education requires second-order intentionality. First-order intentionality is intent to change the behavior of another actor, and this is widespread in the animal world. Second-order intentionality is intent to change the mind (and usually also the behavior) of another animal; this seems absent among animals (or almost so). Although animals are variously socialized, they are not in this sense nurtured. Without some concept of teaching, of ideas moving from mind to mind, from parent to child, from teacher to pupil, a cumulative transmissible culture is impossible. Though language comes naturally to humans, what is learned has been culturally transmitted, using a specific language; the content learned during childhood education is that of an acquired, nongenetic culture.

Religious persons detect a supernature immanent in or transcendent to nature, perhaps even more in human culture. They find that neither nature nor culture is self-explanatory; both point to deeper forces, to a divine presence.

In contemporary biological and human sciences (anthropology, psychology, sociology), as well as in philosophy, there is much effort to naturalize culture, with equal amounts of resistance to such reduction (if that is what it is). Sociobiologists hold that genetic constraints are the principal determinants of culture; only those people and cultures survive that can place genes in the next generation. Evolutionary psychologists discover that humans have an "adapted mind," a modular mind with multiple survival subroutines more or less instinctive—in contrast to the highly rational *tabula rasa* (empty, pliable mind) once favored by humanist philosophers. Philosophical pragmatists may agree that the mind is mostly a survival tool, even in its cultural education.

Culture remains a major determinant, nevertheless. Information in nature travels intergenerationally on genes; information in culture travels neurally as persons are educated into transmissible cultures. The determinants of animal and plant behavior are never anthropological, political, economic, technological, scientific, philosophical, ethical, or religious. Animal imprinting and limited transmitting of acquired information notwithstanding, humans gain a deliberated modification of nature that separates humans in their cultures from nature, increasingly so in high-technology cultures. Since decoding the human genome, completed in 2001, people stand at the threshold of rebuilding even their own genetic nature.

Nature-culture dualism

Humans have a dual inheritance system, nature and nurture. The intellectual and social heritage of past generations, lived out in the present, reformed and transmitted to the next generation, is regularly decisive. Cultures, especially modern ones, change rapidly in a few decades; the human genome hardly changes in thousands of years. Slow-paced genes are difficult to couple with fast-paced cultures.

A relatively pliable, educable mind is as great an adaptive advantage as is a mind with instinctive routines. The mind is so complex that the number of neurons and their possible connections (with resulting myriads of cultural options) far exceeds the number of genes coding the neural system; so it is impossible for the genes to specify all these connections. Human genes have generated an organism whose behavior results from an education beyond direct genetic control. As more knowledge is loaded into the tradition (fire building, agriculture, writing, weaponry, industrial processes, ethical codes, electronic technology, legal history) the genome selected will be one maximally instructible by the increasingly knowledgeable tradition. This will require a flexible intellect, able to accommodate continual learning speedily, adopting behaviors that are functional in whatever cultures humans find themselves. This is consistent with the unusually long period of child rearing in nuclear families with unusually large-brained babies, found in human evolutionary history and uncharacteristic of any other species.

Critics complain that nature-culture dualism is an undesirable Cartesian legacy (perhaps also a Christian or Greek one). The "versus" in the title of this entry frames the connections wrongly. Nature is the milieu of culture, and supposing our cultures to be in exodus from nature is at the root of our environmental crisis. Culture remains tethered to the biosystem, and the options within built environments, however expanded, provide no release from nature. An ecology always lies in the background of culture; no nurture is adequate that forgets these connections.

Perhaps cultural nurturing reinforces natural genetic dispositions for some practices (such as incest avoidance), but not for others (learning nuclear physics). Whether adults have enzymes for digesting fresh milk will determine their pastoral practices. But the differences between the Druids of ancient Britain and the Maoists in modern China are nongenetic and to be sought in the radically differentiating historical courses peculiar to these cultures—even though Druids and Chinese have a biological nature largely held in common and despite differences in skin color or in blood groups.

Humans are only part of the world in biological, evolutionary, and ecological senses—their nature; but *Homo sapiens* is the only part of the world free to orient itself with a view of the whole, to seek wisdom about who they are and where they are, and to develop their lives on Earth by means of culture. Such cumulative, ongoing nurture determines outcomes in the uniquely historical behavior of humans, making the critical difference, while human universals, biological, psychological, or social, which are a legacy of nature, have limited explanatory power.

See also DNA; GENETIC DETERMINISM; GENETICS

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HOLMES ROLSTON, III

NEO-DARWINISM

Neo-Darwinism, the modern version of Charles Darwin's theory of evolution by natural selection, incorporates the laws of Mendelian genetics and emphasizes the role of natural selection as the main force of evolutionary change. The term *neo-Darwinism* was first used in the 1880s by August Weismann, a German naturalist, who incorporated his theory of the germ plasm into Darwin's theory of evolution by natural selection. Weismann advocated the theory that the body is divided into germ cells, which can transmit hereditary information, and somatic cells, which cannot. Weismann thereby added a mechanism of heredity different from Jean Baptiste de Lamarck's inheritance of acquired characteristics, which prepared the ground for the rediscovery of Gregor Mendel's laws of inheritance by Erich von Tschermak, Hugo deVries, Carl Correns, and William Bateson around 1900.

The rediscovery of Mendel's work led first to a critique of Darwin's theory of evolution, as the new school of *Mendelians* (Bateson, deVries, and others) believed that differences in discrete traits among individuals were too big to fit into Darwin's theory of gradual change of phenotypes. Another school of thought that developed during the first two decades of the twentieth century involved the *biometricians* (Karl Pearson, Francis Galton, and others), who opposed the view of the Mendelians and studied small differences in so-called quantitative traits (e.g., body size), using statistical methods and assuming that most genes had only minor effects on traits. The controversy between Mendelians and biometricians was resolved by R. A. Fisher in 1918 when he showed that Mendelian inheritance and gradual changes in phenotypes were not incompatible. In the following two decades Fisher, J. S. B. Haldane, and Sewall Wright used mathematical tools to elaborate on this combination of the laws of genetics and Darwin's theory of evolution, thereby developing the *modern synthesis* and the new field of population genetics.

Modern synthesis, which has since been called the "neo-Darwinian theory of evolution," was soon accepted and integrated into different biological disciplines, including population genetics, comparative anatomy, zoology, biogeography, palaeontology, and systematics. Influential books, such as *Genetics and the Origin of Species* (1937) by Russian-born American experimental biologist Theodosius Dobzhansky, *The Modern Synthesis* (1942) by British biologist Julian S. Huxley, *Systematics and the Origin of Species* (1942) by German-born American zoologist Ernst Mayr, and *Tempo and Mode of Evolution* (1944) by American palaeontologist George Gaylord Simpson are examples of this development and of the neo-Darwinian theory of evolution as having become broadly accepted among contemporary biologists.

Evolution from a neo-Darwinian viewpoint is defined as genetic change in populations through time (descent with change), with modern organisms being descendents of earlier, different organisms. In addition to natural selection, mutation, random genetic drift (i.e., random fluctuations in gene frequencies due to chance), and gene flow are considered important factors of evolutionary change with mutation being the ultimate source of genetic variation.

See also DARWIN, CHARLES; EVOLUTION; GENETICS; LAMARCKISM; MENDEL, GREGOR

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VOLKER LOESCHCKE

NEO-ORTHODOX THEOLOGY

See CHRISTIANITY, REFORMED, ISSUES IN SCIENCE AND RELIGION

NEURAL DARWINISM

Neural Darwinism is a theory of brain development laid out in 1987 by neurobiologist Gerald Edelman (b. 1929). According to this theory, selective forces, both of development and experience, operate on neuronal groups rather than on single neurons. Movement-sensation categories are continually re-categorized, producing maps that interact in ensemble, and establish the coherent temporal patterns of a unified notion of brain. This is an empirically viable neurobiological theory of individuality, about how a person's unique memories, perspectives, and autonomous mental life evolves. The role it may play in a wider theory of consciousness as a kind of "remembered present" is as yet unclear, despite its advantages over other connectionist or neural network models.

See also NEUROPHYSIOLOGY; NEUROPSYCHOLOGY; NEUROSCIENCES

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JOHN A. TESKE

NEUROPHYSIOLOGY

Neurophysiology is the area of neuroscience that studies the functioning of nerve cells, with a primary focus on their information coding, transmission, and storage capacities. Neurophysiology includes study of the electrical properties of the nerve cell membrane, the generation of *action potentials* that carry information, and the communication of this information between cells over the synaptic space. One important question occupying a great deal of time and effort is the nature of changes in synaptic efficiency that occur with learning. The functioning of groups of neurons, including reflex loops and assemblages of neurons into neural networks, is also widely studied.

See also MIND-BODY INTERACTION; NEUROSCIENCES

WARREN S. BROWN

NEUROPSYCHOLOGY

Neuropsychology is the area of neuroscience that studies relationships between brain function and behavior, with a central focus on human brain-behavior relationships. Neuropsychological research attempts to map the brain structures and functions that are critical for particular mental/cognitive, emotional, and behavioral capacities. Clinical neuropsychology involves assessment of persons with diseased or damaged brains to evaluate whether the patient's cognitive, behavioral, or emotional functioning has been compromised. Developmental neuropsychology is the study of the relationship between the development of brain structure and function, and the emergence of cognitive abilities. Finally, neuropsychological rehabilitation attempts to ameliorate the negative impact of brain damage.

See also MIND-BRAIN INTERACTION; NEUROSCIENCES

WARREN S. BROWN

NEUROSCIENCES

Neuroscience is the scientific study of the nervous system and its function. Since the nervous system can be studied at many levels—from the molecular structure of nerve cell membranes to the whole-brain functions involved in the highest of human mental activity—neuroscience is a multidisciplinary field. Neuroscientists might study the nervous systems of simple creatures (e.g., sea slugs), more complex animals (e.g., rats, cats, and monkeys), or human beings. At meetings of the Society for Neuroscience one finds over ten thousand scientists representing a wide variety of fields such as microbiology, histology, neuroanatomy, neurophysiology, physiological psychology, developmental psychology, neuropsychology, neuroradiology, neurology, psychiatry, and cognitive science.

The various domains of research in neuroscience might be grouped into the following topic areas:

- Cellular and molecular neurophysiology;
- Developmental neuroscience;
- Sensory and motor neuroscience;
- Regulatory neuroscience;
- Behavioral and cognitive neuroscience; and
- Clinical neuroscience.

After a brief review of the history of neuroscience, each of these areas will be described. This will be followed by a summary of current research on religious experience and brain function. Finally, the philosophical presuppositions of neuroscience will be briefly summarized.

The history of neuroscience

The ancient-to-modern history of neuroscience involved resolution of four major issues. The first issue was whether mental activity and control of behavior emanated from the brain or the heart. Next, there was the issue of whether the critical parts were the ventricles and cerebral fluids (the pneumatic theory) or the brain tissue itself. When it became clear that the various structures of the brain were the organs of thought and behavior, there was a controversy over localization of these functions in specific brain areas versus a holistic view of brain function. Finally, with respect to neural tissue, research in the late nineteenth and early twentieth centuries established that independent neural cells (neurons) are the basic functional units of the nervous system.

The work of the ancient Greek physician Hippocrates (460–375 B.C.E.) on epilepsy is among the most important ancient contributions to neuroscience. Hippocrates denied that epilepsy was a divine or sacred manifestation, arguing instead that it was a disease of the brain. He considered the brain to be the seat of all mental experience. The alternative view was advanced by Aristotle (384–322 B.C.E.), who is considered by many to be the greatest biologist of antiquity. Aristotle taught that the heart was the center of sensation, movement, and intelligence. Around the same time, important contributions were also being made in Alexandria. Herophilos and Erasistratos (third century B.C.E.) distinguished various brain structures, provided the first description of the ventricles, and associated intelligence with the greater number of convolutions in the cortex of the brain.

The progress of these ancient neuroscientists was extended in the work of Galen (129–199 C.E.) in Rome. Galen contributed important studies of the cranial nerves and the spinal cord. Using transections of the spinal cord, he determined that the spinal cord was an extension of the brain and the conduit of sensory and motor information. However, Galen's theory of brain function was pneumatic, focusing on the ventricles rather than brain tissue. During the medieval period, the theories of Galen became dogma and were transmitted without much modification into the Renaissance.

New advances in neuroscience during the Renaissance were triggered by a rediscovery of the work of the ancients, including descriptions of the original work of Galen. Progress during the Renaissance was made by Andreas Vesalius (1514–1564), who discredited the ventricular theory; René Descartes (1596–1650), who had the idea of the body as a machine and developed the concept of a reflex; and Thomas Willis (1612–1675), an anatomist who provided the most complete description to that date of the anatomy of the brain (and whose book was famously illustrated by Christopher Wren).

The progress in neuroscience achieved in the Renaissance was accelerated during the Enlightenment. Important progress during this period was made by Franz Joseph Gall (1758–1828) and Johann Casper Spurzheim (1776–1832). These investigators proposed that the gyri of the cortex were composed of cells that connected to the brain stem and spinal cord, and, therefore, the cortex could control movement via its connections to the spinal cord. The most famous aspect of the work of Gall and Spurzheim was phrenology, the study of the relationship between skull surface features and mental faculties. What is important about this work is that skull features were thought to reveal the size of underlying cortical gyri, thus phrenology was the first extensive theory of the cortical localization of cognitive functions.

Pierre Flourens (1794–1867) is credited with demolishing phrenology, while advocating the idea that all intellectual functions are coextensive within the cortex (a holist view). Flourens developed the research strategy of removing or lesioning parts of the brains of animals and observing consequent changes in their behavior. However, the localizationist view was kept alive by the work of Paul Broca (1796–1881) and Carl Wernicke (1848–1904), who identified the expressive and receptive language areas of the left cerebral hemisphere (respectively). Based on the discovery of the bioelectric nature of the function of muscles by Luigi Galvani (1737–1798), Gustav Theodor Fritsch (1838–1929) and Eduard Hitzig (1838–1907) demonstrated that the brain was electrically excitable, and that electrically stimulating different cortical locations produced different behavioral effects.

During the nineteenth and early twentieth centuries advances were also being made in understanding the microstructure and microfunction of the nervous system. Due to the availability of improved microscopes, Theodore Schwann (1810–1882) was able to discover and describe the fact that the organs and tissues of animals, including the brain, were made up of many individual cells. However, Schwann believed that the brain, unlike other organs, was made up of cells that were not separated by membranes, but rather were a continuously interconnected network. It took a lifetime of painstaking work by the Spanish neuroanatomist Santiago Ramón y Cajal (1852–1934) to demonstrate that each neuron is an independent and discontinuous cell. Charles Scott Sherrington (1857–1952) was the first to describe the *synapse,* the point of communication between neurons. The microstructure of the nervous system became dynamic with the description of the action potential by A.L. Hodgkin (1914–1998) and A. F. Huxley (1917–). Finally, the hypothesis (since substantiated) that the site of learning within the nervous system is the synapse was advanced in 1949 by Donald O. Hebb (1904–1985).

Cellular and molecular neurophysiology

Cellular and molecular neurophysiology is the study of the molecular structure and physiological functioning of nerve cells. The critical property of a neuron is that it has a membrane that is an electrochemical battery. There is a difference in electrical charge between the inside and outside of the cell created by an uneven distribution of sodium and potassium ions. Also critical to neural function are the processes by which this electrochemical potential can be disturbed so as to trigger an action potential that can be transmitted from one end of an axon to the other. Research has demonstrated that the electrical properties of neurons are based on voltage controlled ion channels within the nerve cell membrane. These channels open or close depending on surrounding voltage levels. Voltage controlled ion channels are the subject of intense study in molecular neuroscience since they are the basis of the resting potential, the excitability threshold of the membrane, the phenomena of the action potential and its transmission, and most of the critical events at the synapse, where information is transmitted from one neuron to another.

Much work in cellular neurophysiology is focused on events occurring at the synapse. In simple outline, it has been demonstrated that the arrival of the action potential at the end of the axon (the terminal button) causes calcium ions to enter the cell. This causes packets of a transmitter substance to release their contents into the extremely small space between neurons. The transmitter substance attaches to receptors on the post-synaptic neuron, causing ion gates to open, resulting in a slight electrical perturbation in this post-synaptic cell. Various other mechanisms have been found that clear activated receptors, take back excess transmitter substance, and recreate the transmitter substance packets.

Another active area of work in neurophysiology is the investigation of the ways that synaptic functions are modified by learning. Using the nervous system of a sea slug, it was demonstrated that learning involved changes in the conductive properties of synapses. Where in the human nervous system such synaptic changes can occur, and how they occur, are important issues in the study of human learning and memory. An important recent advance was the identification of the NMDA receptor that appears to be important in triggering the synaptic changes involved in learning. NMDA receptors are present on neurons within the hippocampus, a brain structure that is known to be important for some forms of memory.

Transmitter substances, and their respective types of post-synaptic receptors, come in a wide variety. Among the major transmitter substances identified are acetylcholine, dopamine, norepinephrine, serotonin, GABA, and glycine, but there are many more than this. There are, for example, at least four variants of dopamine. The field of neuropharmacology attempts to exploit this variety by finding drugs that act in a specific manner on synapses that use a particular neurotransmitter so that specific functions of the brain can be modulated. The drug Prozac, for example, inhibits the reuptake of transmitter substance within synapses that utilize serotonin, causing these particular synapses to be active for a longer period of time.

Developmental neuroscience

Developmental neuroscience studies the fetal and childhood development of the nervous system. There are stages in development of the brain and nervous system: development of cell identity, cell migration, axon growth and guidance, growth of dendrities and synaptic formation, differentiation of connections based on early experiences, and myelinization of axons.

Nerve cells differentiate from undifferentiated stem cells. Stem cells become precursor neuroblasts that eventually produce neurons, glial cells, or other cells within the nervous system. This differentiation process is based primarily upon interactions with neighboring cells. Because of the potency of the influences of neighboring cells in causing undifferentiated stem cells to become neurons, a great deal of research is being done in an attempt to introduce undifferentiated stem cells into the adult brain as a means of reinstituting developmental processes within areas of damaged neural tissue (e.g., stem cells into the spinal cord in individuals who are paralyzed from spinal cord injury).

Cells differentiate into neurons in the middle of the brain surrounding the neural tube and ventricles. However, these cells must migrate outward to form various brain structures. Once cells have migrated to their appropriate place in the nervous system, axons form and begin to grow toward distant targets. For example, neurons in the motor cortex may send axons all the way down into the spinal cord to synapse on motor neurons there. Mechanisms for stimulating and guiding cell migration and axonal growth are topics of intensive study. An example of a congenital brain abnormality related to a failure of appropriate axonal growth is agenesis of the corpus callosum, a condition in which the axons that are supposed to cross between the two cerebral hemispheres do not find their way and, instead, end up traveling toward the back of the brain.

Another important developmental process is the growth of dendrites and the formation of synapses. An interesting aspect of this process is the overexuberance of dendrite and synapse formation in the first two years of life, and the subsequent loss of dendrites and synapses. It is thought that this loss of dendrites and synapses represents brain differentiation based on experience, such that connections that get incorporated into information processing and memory circuits survive, and the others do not survive.

A final developmental process is the progressive increase in myelinization of axons that, in some systems (e.g., the interhemispheric axons of the corpus callosum), are still increasing in myelinization well into the second decade of life. The myelin sheath allows a neuron to transmit actions potentials more rapidly and efficiently. Thus, myelinization of axons contributes to increased cognitive processing speed and power.

Sensory and motor neuroscience

This domain of neuroscience studies the way sensory information (vision, hearing, etc.) is received, coded, and recognized by the nervous system, and the means by which the nervous system controls motor activity in service of both reflexive and purposive movement.

The largest volume of work in sensory neuroscience has involved vision. What is becoming clear from this research is that different properties of the visual signal are processed by separate brain areas. In the cortical area that first receives visual signals, there are different cellular systems for detecting light-dark boundaries and for coding color. As information is further processed, there are separate cortical areas for processing complex visual properties: the parietal lobe for visual guidance of movement, the inferior temporal lobe for object recognition, and a superior temporal area for spatial analysis. Similar processes occur in the processing of sound, touch, and pain. The existence of multiple visual processing areas raises an interesting question regarding how these various sensory properties are reconnected to create a unified percept. This problem is known as the binding problem, a problem that has yet to be solved.

Motor systems are studied by neuroscientists all the way from simple reflexes controlled by the spinal cord, to the voluntary control of skilled movement initiated and regulated by the motor cortex and various subcortical structures. One of the knotty issues in the study of motor activity is determining the modes by which spinal cord reflexes, more complex innate motor responses (such as eating, drinking, sleeping, fear, aggression, etc.), learned habitual behaviors, and conscious voluntary activity are all coordinated with each other and with important vestibular, propriocpetive, and visual sensory information.

Regulatory neuroscience

Regulatory neuroscience studies widely distributed neural and hormonal systems by which the brain influences bodily systems both to insure homeostasis and to prepare the body for particular forms of response to the environment. These neural systems provide regulatory control of breathing, cardiac function, food intake and metabolism, water intake and retention, stress responses, reactions to pain, and sexual development and activity. Regulatory neuroscience overlaps with research in developmental neuroscience with respect to hormonal influences on growth, sexual differentiation, and brain development. The class of regulatory substances called neuromodulators lies somewhere between the direct neural control of bodily systems carried out by the autonomic nervous system, and the release of hormones into the blood stream by the brain's pituitary gland. Neuromodulators are substances that act like synaptic transmitters, but which are released into extracellular space bathing large areas of the brain in order to regulate the general level of activity in specific brain systems.

Another important phenomenon studied within regulatory neuroscience is the interactions between psychological states, brain function, and the activity of the immune system (called psychoneuroimmunology). This research focuses on a number of recently discovered ways by which the neural activity that constitutes certain psychological and affective states (such as responses to stress, general levels of depression or distress, or a sense of well-being) can affect the activity level of the immune system. This area of research is beginning to explain why the belief that one is receiving a beneficial treatment has such a ubiquitous and powerful positive effect on health and recovery from illness (i.e., the placebo effect).

Behavioral and cognitive neuroscience

One of the most significant scientific trends of the latter half of the twentieth century has been the joining of cognitive science and neuroscience into a field called cognitive neuroscience. This field studies the role of various neural systems in complex forms of thought and behavior such as attention, object recognition, spatial orientation, skilled motor activity, language production and comprehension, arithmetic, music, historical (episodic) memory, and the affective-cognitive aspects of social perception.

Methodological developments were an important catalyst for this merger. During the first two-thirds of the twentieth century, methods for studying brain processes contributing to more complex cognition was limited to studies of changes in the behavior of animals created by lesions made in different areas of the brain, or elicited by electrical stimulation of various brain structures. It was also possible to record electrical activity from the depths of the brain of behaving animals. Investigation of human cognition was generally limited to study of individuals with various forms of brain damage, or to brain wave recordings from the scalp.

Technical advances in the methodologies available to neuroscience have remarkably enhanced the ability of investigators to study complex human cognition. Most notable has been the development of the various forms of neuroimaging: computer assisted tomography (CAT), magnetic resonance imaging (MRI), functional MRI (fMRI), positron emission tomography (PET), and single photon emission computed tomography (SPECT). These methods provide the cognitive neuroscientist with noninvasive ways of viewing the structure of the nervous system (CAT and MRI), or the relative level of functional activity of various brain areas (fMRI, PET, and SPECT) in an alive, awake, and mentally active human being.

One example of the kinds of studies that can be done with neuroimaging methods is a 1999 study that compared PET scans taken while Italian-, French-, and English-speaking dyslexic individuals were attempting to read. This research demonstrated that, despite the fact that reading disability took somewhat different forms in the different languages, there was nevertheless a consistent area of diminished brain activity during reading (in the left temporal lobe). This study illustrates the capacity of neuroimaging to reveal, non-invasively, characteristics of human brain processing that occur during a complex cognitive task, such as reading, in normal and cognitively impaired individuals.

Clinical neuroscience

Much of the early history of the field of neuroscience involved the study of individuals with brain damage or brain disease. Studies of patients with epilepsy, brain tumors, traumatic brain damage, or brain diseases (e.g., multiple sclerosis, Parkinson's disease, and Alzheimer's disease) have contributed much to new ideas and theories about how the brain works.

A few individual cases in clinical neurology have been particularly influential. For example, in 1861 Paul Broca (1824–1880) described a patient who had suddenly lost his speech, but was otherwise cognitively normal. The patient has been called "Tan" in the literature, since "tan" was the only word the patient could utter. Autopsy of the brain of this patient showed a lesion of the left frontal lobe, suggesting that this frontal area, subsequently called Broca's area, was important for expressive language. Similarly, a single case referred to in the literature by the initials "H. M." made a substantial contribution to the understanding of explicit, episodic memory. In 1953, H.M. underwent neurosurgical removal of the medial temporal lobes of both hemispheres to control seizures. The result was a profound amnesia in which old memories were preserved, but the ability to form new conscious, explicit memories was permanently lost. This case focused intensive neuroscientific study on the role of the hippocampus (a structure of the medial temporal lobe) in memory formation—research that is still ongoing.

The contribution of new ideas about brain function goes not only from clinical cases to basic neuroscience, but also from neuroscience to clinical medicine. All of the areas of neuroscience described above feed critical information into areas of investigation concerned with those human diseases and disorders of the nervous system that are diagnosed and treated by neurologists, neurosurgeons, psychiatrists, neuroendocrinologists, and neuropsychologists. An example of the impact of basic neuroscience on clinical medicine is the contribution made by studies of the synapse and synaptic transmitters to the development of new drugs that affect the nervous system (neuropharmacology) and behavior (psychopharmacology).

Neuroscientific study of religious experience and moral agency

Most persons identify as most uniquely spiritual their experiences of religious ecstasy and awe—those moments when one feels most transcendent or overwhelmed by the feeling of divine presence. However, the fact that such religious experiences can accompany epileptic seizures (or drug intoxication) has been recognized since ancient times. This observation caused many ancient cultures to associate epilepsy with possession by gods or demons.

There is a significant literature in modern neurology that suggests that in some cases of temporal lobe epileptic seizures, religious experiences result from the abnormal neural activity in the temporal lobes and limbic system. Consistent with the clinical data from temporal lobe epilepsy, investigators have shown that electromagnetic stimulation of the temporal lobes increases the likelihood of experiencing a "sense of presence," leading some investigators to speculate that abnormal temporal lobe activity is the neural basis of all religious experiences.

Other investigators studying the activity of the brain during religious experiences have suggested the importance of other brain areas. Andrew Newburg and Eugene d'Aquili have argued that the sense of diminishment of self and an awareness of oneness with god or the universe that is experienced by some during transcendental meditation or some forms of prayer is associated with diminished activity in the parietal lobes, rather than increased activity in the temporal lobes. These investigators interpret these results as indicating a neural correlate of an absence of the sense of self and the achievement of a sense of "absolute unitary consciousness."

These studies of brain activity during religious experiences at least make it clear that religious experiences (whether feelings of ecstasy, awe, or oneness) have correlates in brain functional states. What is as yet unclear is whether these functional brain states are unique to religious experiences or also occur in similar situations that the person would not report as religious. Is the religious attribution to the experience being studied a matter of the context in which the state occurs, or rather a matter of the particular brain state? Nevertheless, over the last two decades of the twentieth century, there has been increasing interest in the neuroscientific study of religious experiences, such that a new field has taken shape that is being called *neurotheology.*

There has also been considerable neuroscientific study of the processes involved in moral decision-making and moral behavior. A long history of cases from clinical neurology has pointed to the important role of the medial frontal cortex in interpersonally responsible action and moral behavior. Important work by Antonio Damasio has strongly suggested that deficits in these areas involve absence of the unconscious elicitation of negative and positive emotions in relationship to contemplated behaviors, and that the medial frontal cortex is important in triggering emotional reactions to contemplated actions. In a similar vein, fMRI studies of persons attempting to solve moral dilemmas have suggested that areas of the brain involved in emotion are activated to the degree that the particular moral dilemma would demand direct action toward another person.

Philosophy of neuroscience

As is evident in what is described above, neuroscience as a field is committed, to a greater or lesser degree, to four basic philosophical positions: empiricism, physicalism, reductionism, and determinism. Like all science, neuroscience is empiricist in attempting to learn what is true through systematic observations and experimentation. However, neuroscientists might differ regarding whether empiricism is the only contributor to knowledge of truth. Physicalism maintains that human (or animal) mind and behavior are the product of the physical activity of the nervous system. While some neuroscientists might have an extra-scientific commitment to body-soul or mind-body dualism, neuroscientific theory and research would not admit the concept of any nonmaterial entity. Reductionism refers to at least two different positions. Methodological reductionism is merely the idea of breaking more complex things into parts and studying the parts, such as studying changes in synaptic efficiency as a part of what happens in the brain during learning. Causal (or explanatory) reductionism presumes that the causes of any particular mental or behavioral event can be found in more and more elementary mechanisms, such that eventually all mental activity is explainable in a bottom-up manner by chemistry and physics. Some neuroscientists have begun to adopt the concept of non-reductive (or top-down) causal principles emerging within complex systems such as the brain, thus loosening the grip of causal reductionism on neuroscience. However, methodological reductionism is still a predominant principle within the field. Finally, determinism suggests that the physical state of the brain at one point in time is entirely determinative of the immediate future activity of the brain. Certainly, much research in the neurosciences proceeds as if current brain activity is predictive of future brain (mental) activity. However, neuroscientists differ with respect to the question of existence of conscious agency or free will. There is, as yet, no generally accepted theory as to how conscious agency might emerge from brain activity, or how such agency would create a nonreducible causal influence on the processes studied by molecular neuroscience.

See also ARISTOTLE; CONSCIOUSNESS STUDIES; DETERMINISM; EXPERIENCE, RELIGIOUS: COGNITIVE AND NEUROPHYSIOLOGICAL ASPECTS; EXPERIENCE, RELIGIOUS: PHILOSOPHICAL ASPECTS; MIND-BODY THEORIES; MIND-BRAIN INTERACTION; NEURAL DARWINISM; NEUROPHYSIOLOGY; NEUROPSYCHOLOGY; NEUROTHEOLOGY; PHYSICALISM, REDUCTIVE AND NONREDUCTIVE; PLACEBO EFFECT; PSYCHOLOGY

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WARREN S. BROWN

NEUROTHEOLOGY

The term *neurotheology* refers to the attempt to integrate neuroscience and theology. Depending on whether its subject matter is defined in terms of religiosity or human personhood, neurotheology may be divided in two main lines of research.

The first line of research was dominant during the 1970s and 1980s when Eugene d'Aquili, Charles Laughlin, and others attempted to relate neuropsychology to religious phenomena, for example, by looking for the neuropsychological determinants of ritual behavior. Researchers also studied the psychological characteristics linked to dominance of the left or right hemisphere of the brain in relation to various patterns of belief and images of the divine. John Ashbrook suggested the term *neurotheology* for this type of inquiry.

Since the 1980s, the search for specifiable brain structures and brain functioning in correlation to religious or mystical experiences has come to the foreground. Along this line, Michael Persinger as well as Vilayanur Ramachandran have claimed a direct relation between religious experience and temporal lobe activity. Persinger interprets this relationship atheistically, but others point out that it validates neither an atheistic nor a theistic conclusion.

D'Aquili and Andrew Newberg have gone considerably beyond the temporal lobe hypothesis by developing a model for religious experiences that involves the entire brain. This model is based in part on non-invasive neuroimaging of the working brain during ritual behavior and meditation. It is especially this kind of work that is commonly labelled *neurotheology*. Its aim is to explore the question of how religion and God are perceived and experienced by the human brain and mind. This research has revealed that during meditation and worship, the level of activity in those parts of the brain that distinguish between the self and the outside world is diminished. D'Aquili and Newberg regard their research not only as neuroscience but also as a contribution to theology because they feel that it will bring all the elements of religion under one rational explanatory scheme, namely that of neuroscience.

The second line of research concerns a portrayal of human personhood, which is both neuroscientifically and theologically accurate. The neuroscientific discourse on the human person, increasingly vocal since "the decade of the brain" (1990–2000), seems to be at variance with theological discourse on that subject. In the latter, mind and soul, free will, consciousness, responsibility, and the human being's contact with God are thought to be fundamental characteristics of the human person. In neuroscience, all of these are either seriously doubted or reduced to their underlying material relationships.

This second type of neurotheology aims at improving the compatibility of theology and neuroscience with regard to the concepts of human personhood. Here, conceptual analyses, such as the analysis of free will, and concepts from the philosophy of mind, such as supervenience, play an important role. The work of the international research group co-sponsored by the Vatican Observatory and the Center for Theology and the Natural Sciences in Berkeley, California, represents this type of inquiry. Beyond compatibility, this "neurotheology of the person" also aims at the mutual enrichment of theology and neuroscience. Whereas the latter may help theology incorporate materiality in its conceptions of human personhood, theology may stimulate neuroscience to be mindful of the more holistic or synthetic characteristics of being human.

See also COGNITIVE SCIENCE; CONSCIOUSNESS STUDIES; EXPERIENCE, RELIGIOUS: COGNITIVE AND NEUROPHYSIOLOGICAL ASPECTS; EXPERIENCE, RELIGIOUS: PHILOSOPHICAL ASPECTS; FREEDOM; NEUROSCIENCES; PRAYER AND MEDITATION; SOUL

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PALMYRE OOMEN

NEW PHYSICS

The term *new physics* refers to a range of fundamental developments and paradigm shifts that occurred in the physical sciences during the last half of the twentieth century. These include the theory of quarks, which is essential to the standard model of fundamental particle physics; the study and application of macroscopic manifestations of quantum phenomena such as superconductivity, superfluidity, lasing, and other types of spontaneous quantum self-organization; the realization of electroweak unification and the quests for grand and total unification of the four fundamental interactions; the burgeoning successes in gravitational physics, including gravitational wave and black hole physics; and inflationary, fundamental-particle, and quantum cosmology, which ultimately rely on total unification and quantum gravity schemes.

Another component of the new physics is the study of chaos and complexity, which involves modeling complex physical processes using nonlinear, often dissipative, deterministic mathematical systems in which there is extreme sensitivity to initial conditions, leading to loss of predictability, the importance of top-down causality together with a lack of reducibility to more fundamental systems and processes, and the emergence of higher-level self-organization out of lower-level erratic behavior. Some of the key features of the new physics are the fundamental indeterminism at the basis of all quantum phenomena due to the Uncertainty Principle, and the appearance of one of more levels of global chaotic or self-organizing behavior accompanied by radical unpredictability and irreducibility in complex systems, such as fluid turbulence, weather systems, and the dynamics of insect populations.

See also COSMOLOGY, PHYSICAL; GRAND UNIFIED THEORY; PHYSICS; PHYSICS, QUANTUM

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WILLIAM R. STOEGER

NEWTON, ISAAC

When a tiny and frail boy was born in the obscure Lincolnshire hamlet of Woolsthorpe on Christmas Day 1642, the attendant maids did not believe he would survive the hour, let alone eighty-four years. As it was, Isaac Newton went on to become a Fellow of Trinity College and the Royal Society, Cambridge's second Lucasian Professor of Mathematics, the author of the *Principia mathematica* (1687) and the *Opticks* (1704), a member of Parliament, Master of the Royal Mint, a knight and President of the Royal Society. When he died in 1727, he was given a state funeral and buried in a place of honour at Westminster Abbey. His work in physics gave us universal gravitation, a mathematical explanation for the elliptical orbit of planets, and a precise celestial mechanics that still serves the world in the space age. His optical experiments confirmed the heterogeneous nature of white light, and he constructed the first practical reflecting telescope. He discovered calculus and showed more than any other thinker before him how well mathematics could explain the workings of the universe. Hagiographic celebrations of Newton in the years and decades after his death ensured his fame as an enduring icon of science and as having produced one of the greatest revolutions ever in the study of nature. But the range of his intellectual endeavour was even broader than this. What is less well known is that for more than half a century Newton was carrying out a private revolution in theology.

Newton's science and his religion

When the young Cambridge-educated clergyman Richard Bentley was called upon in 1692 to deliver the first Boyle Lectures for the defence of Christianity against infidelity, he buttressed his natural theological arguments for the existence of God with support from Newton's *Principia*. While revising his lectures for the press, he wrote the author of the *Principia* to determine if his deployment of its physics would meet the approval of the great man himself. In his first reply to Bentley Newton confirmed: "When I wrote my treatise about our Systeme I had an eye upon such Principles as might work wth considering men for the beleife of a Deity & nothing can rejoyce me more then to find it usefull for that purpose." Newton went on and asserted that "ye diurnal rotations of ye Sun & Planets as they could hardly arise from any cause purely mechanical … they seem to make up that harmony in ye systeme wch … was the effect of choice rather than of chance."

Even though Newton's letters to Bentley were published in 1754 and thus became part of the public record, the *Principia*'s original theological backdrop receded in the wake of the profoundly successful Enlightenment portrayal of Newton, which made him the patron saint of the Age of Reason. It was in the eighteenth century that the still-common association between Newton and the secular clockwork universe emerged. Yet the notion of a self-sustaining clockwork universe, originally wound up at the beginning by a remote deity, is precisely the sort of view of creation and providence that Newton himself opposed in the General Scholium, which portrays the biblical "Lord of Lords" as a personal God with an ongoing, interventionist relationship with creation. Enlightenment apologists and later positivist scientists also developed the two variations of the "Two-Newton" thesis: first, that Newton only turned to theology with old age and dotage (and thus after the "first Newton" had produced his great works of science) and, second, that Newton kept his science separate from his religion in a kind of early modern anticipation of methodological naturalism. Although the vestiges of the second variant of the Two-Newton thesis can still be found in current literature, the recent availability of Newton's long-inaccessible manuscripts for study has made such claims untenable. A steadily increasing body of scholarly literature is both explicating Newton's theological views (the main contours of which were mainly in place *prior* to or around the time of the appearance of his *Principia*) and revealing ways in which his theology interacted with his natural philosophy. Although some of the conclusions will remain tentative until the manuscript corpus has been thoroughly analyzed, the view of Newton now emerging is that of a natural philosopher who was both profoundly religious and who saw no firm cognitive barrier between theology and the disciplines now called scientific. Isaac Newton the natural philosopher cannot be understood apart from his religion.

Newton's theology and prophetic studies

In addition to being the preeminent natural philosopher in the West in the late seventeenth and early eighteenth centuries, Newton was a theologian and prophetic exegete in his own right. It is also now known that he left behind one of the largest corpora of theological writings in the early modern period (totaling as much as four million words). In his zeal to plumb the depths of biblical theology and comb the records of the early church, Newton far out-stripped all but a few of his contemporaries, including those known as divines or religious figures in the first instance. Newton himself was to remain a lay member of the Church. When Newton became a Fellow of Trinity College, Cambridge, he was obligated to become ordained as a priest in the Anglican Church by 1675. The impending deadline was likely one motivation for the initiation of a comprehensive study of Christian theology and ecclesiastical history that began by the early 1670s. But as the deadline neared, Newton sought ways to avoid taking holy orders. An eleventh-hour exemption from ordination (granted by no less a personage than King Charles II) allowed him to avoid the resignation of his fellowship, which he had been prepared to do. Whatever academic reasons Newton may have had for avoiding ordination, theological discoveries that he made by the early 1670s made ordination (and subscription to the Anglican Thirty-nine Articles) impossible. Among the results of Newton's early theological studies was the conclusion that Christianity's chief doctrine, the Trinity, was a corruption deviously imposed on the Church in the fourth century by Athanasius.

Newton gravitated toward the position of the fourth-century Arians who, according to Trinitarian historiography, were the doctrinal losers in the Christological controversies of that era. As in Arianism, Newton viewed the Father as the only true God, while Christ was of a lesser status and nature, albeit pre-existent before his appearance on Earth. But Newton's Christology was not precisely isomorphic with Arianism, and his discomfort over the Athanasian injection of the Greek notions of essence and substance into Christian theology extended to the Arians, who conceived of Christ as being of similar substance (*homoiousios*) to the Father, while the Athanasian Trinitarians saw Christ and the Father as of the same substance (*homoousios*). In his stress on the moral rather than the essential relationship between the Father and Son Newton's theology shows affinities with that of the seventeenth-century Socinians and English Unitarians, some of whose works were in his library. It is also evident that Newton's powerfully monotheistic conception of a unipersonal "God of dominion" owes something to Hebraic and Judaic thought.

Nor did Newton's heresy stop here. By the early 1690s his study of key biblical texts led him to reject the orthodox doctrine of the soul's natural immortality in favour of a mortalist viewpoint. For Newton such texts as Psalms 6:5 and Ecclesiastes 9:5 and 9:10 demonstrate that there is no intermediate conscious state between death and resurrection. Around the same time Newton concluded that demons (thought by many in his day to be departed spirits) in the Bible were not literal evil spirits, but rather delusions or distempers of the mind. Similarly, Newton rejected the belief that Satan is a fallen angel, asserting instead that the devil is a symbol of human lust and ambition. His final position on the devil is almost identical to the Jewish teaching of *yetzer ha-ra* ("the evil inclination"), in which sinful desires are personified as Satan. Newton's conception of human temptation thus shifted from a focus on external and ontologically real evil spirits to a psychology of the inner demons of the mind.

Denial of the Trinity was illegal in Newton's day and for many years afterward. The rejection of the soul's immortality was viewed as scandalous and the denial of evil spirits was seen, ironically, as tantamount to atheism. Until his dying day Newton hid these maligned heresies from the notice of all but a few trusted confidants. Although kept secret, Newton's heterodox theology was at the core of his existence and helped to shape many aspects of his thought, including his natural philosophy. While heretical from the perspective of traditional Christianity, these departures from orthodoxy do not make Newton into some sort of protodeist. On the contrary, Newton was a fervent biblicist who always cast his theological language in scriptural terms and supported his views amply with biblical texts. Newton's friend the philosopher John Locke, who was also a lay student of the Bible, once referred to Newton as "a very valuable man not onely for his wonderful skill in Mathematicks but in divinity too and his great knowledg in the Scriptures where in I know few his equals." Newton knew his Bible; he believed it too.

No true deist adheres to the literal fulfilment of biblical prophecy, and Newton was nothing if not passionate about just that. Newton wrote his first monumental treatise on the Apocalypse in the 1670s and continued to study prophecy until his death. He was fascinated by the symbols of biblical prophecy and methodically developed a lexicon of prophetic emblems. He also produced studies of the architectural structure of the Jerusalem Temple. Following Cambridge's Joseph Mede, Newton's eschatology was premillenarian. Newton believed that the Jews would be restored to Israel, the Temple rebuilt in Jerusalem, and that Christ would return to the earth in the future to set up a terrestrial Kingdom of God (which he put off to no sooner than the twentieth century). As with his theology, Newton's prophetic views were virulently anti-Catholic. Newton departed from most of his contemporary Protestant prophetic exegetes, however, in placing the doctrine of the Trinity at the center of the great apostasy.

The fulfilment of prophecy also provided Newton with one of the best lines of evidence for the existence of God. In his posthumously published *Observations* (1733), he wrote that "the event of things predicted many ages before, will ... be a convincing argument that the world is governed by providence." At the same time, he looked askance at exegetes who overconfidently set dates, believing that such enthusiasm inevitably brought discredit on Christianity when the predicted dates failed. When speaking about a particular prophecy in his *Observations,* he wrote: "The manner I know not. Let time be the interpreter."

Religious motivations for Newton's natural philosophy

Newton's theology related to his natural philosophy at two levels. First, in a general way Newton's piety and religious beliefs acted as a stimulus to the study of nature (the weak relationship between science and religion). Second, in some cases the particulars of Newton's theology helped shape the cognitive content of his physics and mathematics (the strong relationship between science and religion). Beginning with examples of the first type, Newton had imbibed the seventeenth-century Protestant culture of natural theology and, like the chemist Robert Boyle, saw himself as a priest of nature. Manuscripts dating from around the time of the *Principia* indicate that Newton believed the priests of the Urreligion (for Newton a prescriptive ideal) were also adept natural philosophers. The study of nature, then, was intrinsically related to piety and could itself be a form of worship and devotion. Religion and piety served as a stimulus to unravel the secrets of nature. Newton's adherence to the Renaissance notion of the *prisca sapientia* (lost ancient wisdom) served as one common motivator of both his natural philosophy and his religion, with Newton striving to recover the original, pure manifestations of both. Like other natural philosophers of his age, Newton believed that natural philosophy had as one of its chief ends the understanding of God and his attributes. Thus, he held that one aim of experiment, which he promoted assiduously as President of the Royal Society, was to discover God's attributes. Moreover, because he also was committed to the *topos* of the Two Books—that God has revealed Himself in both the Book of Scripture and the Book of Nature—Newton employed similar methods of analysis in his natural philosophy and his theology. Analogies between Newton's prophetic hermeneutics and his natural philosophical methodology may also be explained by his commitment to the Two Books. Newton used the distinction between the absolute and relative in both his science (to distinguish absolute and relative time and space) and his theology (e.g., to distinguish between the absolute and relative use of the term *God*). In his theology Newton adhered to an epistemological dualism in which he divided knowledge into open and closed levels. This esoteric-exoteric divide, which may owe something to Newton's involvement in alchemical networks, was also operative in his natural philosophy. Other examples of the weak relationship could be cited. For example, Newton's animosity toward Jesuit critics of his optics can be illuminated by an understanding of his theologically inspired animus against Catholicism.

Newton's aforementioned letters to Bentley confirm his adherence to natural theology. Newton's belief in the argument from design was given public acknowledgement when he added his General Scholium to the conclusion of the second edition of the *Principia* in 1713. In this new appendix Newton states confidently that "This most elegant system of the sun, planets, and comets could not have arisen without the design and dominion of an intelligent and powerful being." The theological part of the General Scholium concludes with the claim that discoursing of God "from phenomena is certainly a part of experimental philosophy" ("natural philosophy" in the third edition of 1726). This was not Newton's only public articulation of the design argument; the later editions of his *Opticks* also conclude with powerful expressions of natural theology. In one of his unpublished papers he wrote that "God is known from his works," thus confirming a natural theological empiricism that he shared with such contemporaries as Boyle. In a document dating from the early 1690s, Newton stated: "there is no way (without revelation) to come to the knowledge of a Deity but by the frame of nature." There was also an apologetic edge to Newton's use of the design argument, and in one place he wrote that "Atheism is so senseless & odious to mankind that it never had many professors," and then went on to speak about symmetry and unity in nature, citing the fact that animals share homologies in their physiological structures.

Newton's adherence to the Two Books tradition is made plain in his early treatise on the Apocalypse, where he argues that the same "God of order" who embedded simplicity in creation also ensured that the fundamental meaning of biblical prophecy would be simple. This analogy between parsimony in Scripture and nature helps explain why Newton believed that similar inductive methods could be utilized in the interpretation of both Books:

> It is the perfection of God's works that they are all done with the greatest simplicity. He is the God of order not confusion. And therefore as they that would understand the frame of the world must indeavour to reduce their knowledg to all possible simplicity, so it must be in seeking to understand these visions.

For Newton all truth (God's Word and God's Works) is a unity because all Truth comes from the same, powerful Deity.

Newton's theology and the content of his natural philosophy

Examples of the weak relationship between theology and natural philosophy in Newton's career serve as the substratum for cases of the strong relationship, which has only recently begun to be presented by scholars with force. It goes without saying that interaction between matters of faith and facts of nature should be entirely plausible for a scholar who was committed to the Two Books tradition and for whom there were no rigid methodological or conceptual barriers between theology and natural philosophy. Nevertheless, the strong relationship is more difficult to convey and, while certain examples (such as Newton's conception of space as the divine *sensorium*) are transparent, some case studies used to confirm it still require further investigation and refinement.

First, it is evident that some examples of the weak relationship or analogies, on closer inspection, lead into strong ones. This is the case with the symmetry between Newton's prophetic hermeneutics and his natural philosophical methods, for Newton's rules of reasoning in the final edition of the *Principia* appear to have been related to or even based in part on his rules of prophetic interpretation, which were written decades earlier. And the analogy between the methods of interpretation in both these disciplines is itself based on Newton's conception of God. Just as René Descartes used God to guarantee deductive logic, so Newton employed the guaranteeing God to support his use of induction. For Newton natural philosophers can use inference in experimental philosophy precisely because the faithful God of order allows one to expect parsimony in nature and since the unity of creation ensures that specifically observed principles and structures point to universals.

Newton's conception of space and time is thoroughly imbued with a profound sense of God's omnipresence and omnitemporality. For Newton absolute space is rigid and immovable, thus providing a stable frame of reference within which relative motion occurs. All of this is possible because absolute space is coextensive with God's omnipresence, a belief Newton came to in part from his exposure to the Rabbinical notion of God as *māqôm* ("place"). As J. E. McGuire put it, space for Newton was God's "sacred field." Similarly, Newton conceived of absolute time as flowing evenly and uniformly largely because it is coterminus with God's eternal duration. Newton's calculus also depended on his conception of absolute time, which for Newton rested on a belief in God's eternal, evenly flowing duration. God's omnipresence further provided an explanation for the phenomenon of gravity, and in private Newton speculated that God was the upholder of universal gravitation. His notion of attraction may have also owed something to his engagement with alchemical doctrines. Newton saw the deity as a God of dominion who ruled creation directly and continuously, intervening with particular providence when necessary to keep history or nature on track. Here Newton's view of the providence of nature stands in stark contrast to that of Gottfried Leibniz, whose *Supramundana* used his supreme intelligence and perfect foreknowledge to set the world in motion at creation, obviating the need for intervention. The differences between these two views are articulated eloquently in the famous debate between Leibniz and Newton's disciple Samuel Clarke.

Newton's distinction between absolute and relative space and time has a heretical corollary, since in his theology God is equated with immovability and the absolute, and Christ with motion and the relative. It is also likely that Newton's antitrinitarian view of a unipersonal God supported his understanding of the unity of nature. That even the heretical elements of Newton's theology permeated his natural philosophical program is made plain by his General Scholium, which, although an appendix to an ostensively purely natural philosophical work, is embedded with antitrinitarian biblical hermeneutics, in addition to its more overt anti-Cartesian stance. For Newton, the feigned natural philosophical hypotheses of Descartes are no different than the vain doctrinal hypotheses of Trinitarianism. Corrupt interpretative practices in natural philosophy and theology are linked, just as the correct methods of arriving at Truth are unified. Newton's General Scholium epitomizes his dual reformation, a grand program that sought to restore the original, pure forms of both natural philosophy and religion.

Newton's integrated program for science and religion

The foregoing must not be taken as evidence that it was only the case that Newton's theology informed his natural philosophy, but not the other way around. The same considerations that explain the first dynamic also make the reverse perfectly reasonable. Thus, Newton's methodological approach to the interpretation of prophecy may owe something to his satisfaction with the results of mathematics, although Whiston records that when pressed Newton eschewed the notion that prophecy could be demonstrated. It is also clear that Newton's conception of God was in part based on a possibly unconscious desire to create God in his own image: in his letters to Bentley Newton spoke of the "cause" of the solar system as not "blind & fortuitous, but very well skilled in Mechanicks & Geometry"—a characterization of God in keeping with the views of Galileo and Johannes Kepler before him, and one in which a vestige of Platonism is in evidence.

Newton's published and unpublished writings demonstrate that his religion interacted with his natural philosophy at a high level. Newtonian physics cannot be disentangled from Newtonian theology. Although it is clear that Newton recognized disciplinary and methodological distinctions, the lack of firm barriers within Newton's intellectual life suggests that it is problematic to speak in terms of "influence" of one sphere on another. Instead, Newton's lifework evinces one grand project of uncovering God's truth. Science and religion for Newton were not two completely distinct programs, but two aspects of an integrated whole. For Newton, the unity of truth meant that there was ultimately one culture, not two.

See also CLOCKWORK UNIVERSE; GOD; GRAVITATION; NATURAL THEOLOGY; REVELATION; TWO BOOKS

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STEPHEN D. SNOBELEN

NONFOUNDATIONALISM

Nonfoundationalism (or anti-foundationalism) is a philosophical view that is dialectically defined by its negation of *foundationalism*. Rejecting the asymmetric image of basic (immediately justified, foundational) beliefs that support nonbasic beliefs, nonfoundationalists prefer the image of a web of mutually supporting beliefs, which are mediated through a particular community. Nonfoundationalists in theology have drawn attention to the way in which doctrine operates as an intrasystematic grammar that regulates the form of life of a believing community. Insofar as they reduce doctrinal beliefs to this function, they are susceptible to the same objections that are generally raised against relativistic forms of coherentism and pragmatism.

See also FOUNDATIONALISM; POSTFOUNDATIONALISM

F. LERON SHULTS

NONLOCALITY

See LOCALITY; PHYSICS, QUANTUM

NONREDUCTIVE PHYSICALISM

See PHYSICALISM, REDUCTIVE AND NONREDUCTIVE

NUCLEAR ENERGY

Nuclear energy, strictly conceived, has received rather scant attention within the literature of science and religion. However, if the focus is broadened to include nuclear technology—that is, nuclear energy and nuclear weapons considered together—then there is a modest increase in its treatment.

Benefits and risks

Nuclear energy has long been viewed as an alternative energy source to coal and petroleum, which are currently the principal sources of energy. Coal and petroleum provide efficient sources of energy, but their combustion also generates considerable carbon dioxide that escapes into the atmosphere. Although a few dissenters remain, the vast majority of climatologists hold that the build up of carbon dioxide in the atmosphere creates a greenhouse effect. This greenhouse effect dramatically warms the planet, which leads, in turn, to global climate change, resulting in different impacts on different regions of the planet.

Nuclear energy provides an especially attractive alternative to coal and petroleum because it does not contribute to the concentration of carbon dioxide in the atmosphere. Shifting to nuclear energy could potentially lead to a cleaner, healthier environment without a reduction in the human consumption of energy. However, the benefits of nuclear energy must be weighed against its substantial costs and risks. The principal cost of nuclear energy occurs with the safe disposal of radioactive wastes. In addition to the costs of disposal, there is the risk that nuclear radiation could be released into the environment, either at the nuclear power plant or at the site of waste disposal. Such a release could be accidental, the result of equipment malfunction or human error. There is also the risk of an intentional release of nuclear radiation as an act of terrorism. Whether accidental or intentional, such a release could potentially destroy all biotic life in the affected area and make the area sterile for life for the foreseeable future.

Although as of 2002 there have been no intentional releases of nuclear radiation into the environment, there have been two serious accidents at nuclear power plants. In 1979, there was an accident at the Three Mile Island nuclear power plant in Pennsylvania. There was another accident in 1986 at the Chernobyl nuclear power plant in Ukraine. Although very little nuclear radiation escaped from the Three Mile Island accident, nuclear radiation did escape from the Chernobyl accident, causing substantial ecological damage and the deaths of a number of people.

Theological perspectives

Within the science and religion literature, Ian Barbour provides one of the few focused treatments of nuclear energy in his book *Ethics in an Age of Technology* (1993). Barbour begins his examination with a discussion of risk. If risk is defined as the probability of an accident multiplied by the magnitude of its consequences, then the risk posed by nuclear energy is low, compared to other daily activities, such as driving a car. However, Barbour argues that evaluations of such technological risks must also be influenced by assumptions about human nature and social institutions. Taking a Christian religious perspective, Barbour argues that the individual and social sin inherent in the human condition calls for extreme caution in the development of nuclear energy because the risks and consequences are so high.

Shifting his focus to the safe disposal of radioactive wastes, Barbour identifies three ethical issues. First, Barbour notes that an issue of regional justice arises because radioactive waste disposal imposes extreme risks for a local population in order to provide a national benefit for everyone. Intergenerational justice raises a second ethical issue. The present generation would enjoy the benefits of nuclear energy, but passes on some of the burdens and risks of waste disposal to future generations. Finally, Barbour identifies the loss of public confidence in governments and the energy industry as a third ethical issue. His point here is that historically government and industry have been secretive and have failed to protect the public, rather than being transparent and promoting public discourse concerning the benefits, costs, and risks of nuclear energy. Barbour believes that more promising energy alternatives lie in energy conservation and in the use of other renewal energy sources, such as solar power.

In the 1980s, several religious writers warned that nuclear weapons and nuclear war threatened not only human life but the ecological viability of the planet. Two Christian theologians, Gordon Kaufman and Sallie McFague, argued further that these interconnected challenges were rooted in what has become a flawed understanding of God's power. In *Theology for a Nuclear Age* (1985), Kaufman argues that the threat of nuclear war and annihilation elicits two contrasting responses from traditional Christian conceptions of God. On the one hand, nuclear annihilation is interpreted in eschatological terms as God's action to bring the present age to an end. On the other hand, the threat of nuclear war is discounted because of the view that an almighty creator God, who loves humans and the rest of creation, would not allow such a disaster to occur. Kaufman notes that both responses have the effect of obscuring and undermining the responsibility that humans have for their actions. While the traditional understanding of God as omnipotent may have been appropriate for earlier times, Kaufman argues that this understanding is no longer appropriate in a nuclear age. In light of the threat of nuclear weapons, Kaufman proposes that Christian theologians need to reconceive of God's power, moving from a dualistic to an interdependent understanding. This would require theologians to rethink their formulation of the symbols "God" and "Christ." McFague concurs with Kaufman's analysis in her book *Models of God: Theology for an Ecological, Nuclear Age* (1987). As alternative models for thinking about God, McFague proposes mother, lover, and friend.

While both Kaufman and McFague were thinking initially of the threat of nuclear annihilation, they both extend their analyses to include ecological concerns. Thus, whether conceived broadly as nuclear technology, or more narrowly as nuclear energy, the literature of science and religion has consistently seen critical ecological implications for the planet.

See also ECOLOGY; ECOLOGY, ETHICS OF; ECOLOGY, RELIGIOUS AND PHILOSOPHICAL ASPECTS; ECOLOGY, SCIENCE OF; GREENHOUSE EFFECT

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RICHARD O. RANDOLPH

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OMEGA POINT THEORY

The concept of the Omega Point in science and religion discussions was introduced by Jesuit paleontologist Pierre Teilhard de Chardin (1881–1955) as a reference to Christ as the final goal of the evolutionary process. The Omega Point Theory, inspired by the language of Teilhard, is quite distinct from Teilhard's original idea. This theory was put forward by physicist and mathematician Frank Tipler in a series of articles in the late 1980s and popularized in his 1994 book *The Physics of Immortality*. Tipler theorizes that all matter will converge to an infinite all-knowing point at the end of a closed universe and that this point to which the universe is moving is the Omega Point. This Omega Point is the "god" that necessarily exists but is not the personal God of traditional theism.

See also CLOSED UNIVERSE; COSMOLOGY; TEILHARD DE CHARDIN, PIERRE

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MARK WORTHING

OMNIPOTENCE

Divine omnipotence means that God possesses all power and potency without any external limitation. The notion of omnipotence indicates a basic principle for the description of divine agency within monotheistic thought. However, in a monistic and emanative conception of God (e.g., as the perfect One in the philosophy of Plato and Plotinus, or Baruch Spinoza's idea of the intrinsic unity of perfection, necessity, and reality), there is no need of divine action. Within theism, divine omnipotence means the power to do all possible things that are not contrary to God's will and knowledge. The concept of God is often characterized by omnipotence in the description that God is the all-determining reality (Wolfhart Pannenberg), although others regard omnipotence as a projection of human desires onto an illusory, usually male, godhead (Sigmund Freud).

The idea of omnipotence comprises not only the actual reign over all human history as *Pantokrator* (the Septuagint translation of the Hebrew *YHWH Sebaoth* [Psalms 24:10], meaning "the almighty" and "the ruler of all things"), but also God's unlimited potential for agency (Augustine of Hippo), and for that reason it is religiously an argument for trusting God's guidance of salvation history. Therefore, it relates the concepts of creation and providence; the omnipotent God sustains the created reality. Since medieval theology, a distinction is made between the *potentia absoluta* (by which God can effectuate all non-self-contradictory possibilities) and the *potentia ordinata* (power limited by God's decision to create and maintain the orders of nature and of grace). God's creative power is neither exhausted by creating the natural order nor determined by it but makes room for the miraculous. The notion of ordained power signifies the complete absence of arbitrariness in God's agency. Sometimes theologians and philosophers neglected the religious meaning of omnipotence by speculating on the boundaries of God's absolute power, whether, for example, laws of logic or mathematical principles were created and maintained by divine power like the laws of nature (René Descartes). Although the notorious paradox of the stone (can an omnipotent being make a stone that it cannot lift?) seems to contradict the possibility of divine omnipotence, it is more a curious puzzle that has, however, a theologically more important equivalent. That is: Can the omnipotent God create people who are agents with a free will without simultaneously losing the control of the course of human history?

This question relates to the problem of evil: Can one believe in God almighty who is simultaneously omniscient and perfectly good, and who creates human agents with moral freedom and responsibility, and who permits suffering in the world? Is such a concept of divine omnipotence consistent? Process theologians, like Charles Hartshorne, try to avoid this dilemma by claiming that God's power is finite and limited by the freedom and power of human creatures. This kind of balance, however, presupposes a quantitative distribution of power at the same level, whereas providence entails divine omnipotence sustaining the created power at a different level. The so-called "free will defense" argues that the possibility of evil is given with the human reality of moral responsibility (Alvin Plantinga). This concept is compatible with God providing room for human freedom by limiting divine omnipotence (i.e., by not permanently actualizing it in all its respects). But it does not touch the problem of natural evil (diseases, floods, etc.). In light of this, the question can be raised whether we may refer to God as *perfectly* good when this same God created a universe in which moral and natural evil are possibilities. Moreover, when we consider the possibility that this may be a universe over which God, after the act of creation, has no further control, and thus cannot influence the outcome of events, we might consider such a God morally blameworthy for taking the initiative of creation.

See also AUGUSTINE; CREATION; DESCARTES, RENÉ; DIVINE ACTION; EVIL AND SUFFERING; FREEDOM; FREE WILL DEFENSE; FREUD, SIGMUND; GOD; MIRACLE; OMNISCIENCE; PLATO; PROCESS THOUGHT; PROVIDENCE; THEODICY

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LUCO J. VAN DEN BROM

OMNIPRESENCE

The divine attribute of omnipresence is the theological interpretation of God's hiddenness, whose presence in history is unlimited and transcends local space. Concepts like transcendence, immanence, agency, knowledge, indwelling, place, and spiritual substance are basic to omnipresence. God's omnipresence is an active presence, which means that creation and providence find their place within God's creative presence. Classical theology distinguishes omnipresence by virtue of power, knowledge, and being. Divine power fills everything and God's being is by nature wholly present in all things, therefore God's place is where the divine power and activity manifests itself as dynamic omnipresence. Divine presence by virtue of knowledge means that every entity is created in accordance with divine ideas and is thus mentally present to God.

After the demythologization of "heaven above," the question is how to imagine the relation between the divine sphere and the world of human experience. Is God's presence spatial or nonspatial? An answer to this question depends on the theory of space people handle. One can distinguish idealistic, realistic, and relational theories. An idealistic theory of space denies the independent existence of space, but holds that one's observing capacity arranges objects spatially. A realistic theory holds that space exists independently of the objects therein or of any observer. A relational theory claims that space is given with objects in their mutual relations, as the order of coexistent things.

Three theories interpret God's omnipresence by means of a realistic theory of space. *Absolute monism* imagines that God and created reality coincide (Baruch Spinoza: *Deus sive natura*). *Organic monism* interprets the relation between God and the world as a psychosomatic unity, thus the world is God's body. God is both present in and all over the world and transcends the world at the same time (Grace Jantzen; process theology). *Spatial dualism* conceives God's omnipresence as extended in absolute space without coinciding with the created world. God is thought of as active everywhere and therefore God is also substantially present everywhere as an omnipresent non-material substance (*no actio in distans,* Isaac Newton).

Traditionally theologians have thought of God's active presence as the universal, nonspatial, sustaining principle that prevents disintegration (Anselm of Canterbury), or as the nonspatial, spiritual cause of the hierarchy of created causes (Thomas Aquinas). Because God is "simple" or nondivisible, God is, as a whole, in every place (Augustine). Although these theologians presuppose a realistic theory of space, their view appears to be compatible only with idealistic theory.

Given the scientific picture of the world, God's omnipresence is imagined as God's own space (Karl Barth). With reference to mathematical conceptuality in natural science one can picture three-dimensional space as a subspace of an infinitely higher dimensional space in which God exists (Karl Heim). Now omnipresence means that within God's own space of an infinite number of dimensions, God is present in every position in three-dimensional space. Thus, God is simultaneous with all objects in three-dimensional space, without being contained by this three-dimensional space or four-dimensional space-time (Luco van den Brom).

See also AUGUSTINE; GOD; MONISM; NEWTON, ISAAC; THOMAS AQUINAS

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OMNISCIENCE

Omniscience concerns God's (a priori) knowledge about the course of people's lives. More generally, it concerns God's knowledge about the whole course of history, including the future. This appears in that aspect of prophetical literature that expresses itself in a forecasting style, which, in turn, rests upon divine foreknowledge.

In the biblical literature, knowledge of the future is a distinctive characteristic of God over against pseudo-gods. In Christian theology, the notion of omniscience refers to the property by which God knows all past, present, and future things and all events, including all their circumstances and boundary conditions. Omniscience encompasses both the actual and possible things and events in past and present, but it includes knowledge of the possibilities that will be actualized as well as those that will not be actualized. Divine knowledge is therefore perfect as absolutely true. But characteristic of divine omniscience is also its immediate (intuitive) nature: It will never be discursive by means of any mediating epistemological process of experience and deduction.

The classical notion of divine omniscience states that God knows all events in past, present, and future simultaneously—in one perspective, from the eternal (timeless) stance outside of time. Therefore, God knows all things "from eternity" at once because this knowledge transcends every temporal order, including that of its epistemological object, for example, the temporal course of the historical process, as discussed by the Roman philosopher Boethius (c. 480–524) and the Christian theologians Augustine of Hippo (354–430) and Thomas Aquinas (c. 1225–1274). Boethius's metaphor describes the all-knowing God outside time like a person who stands on the top of a mountain and sees what happens along the road in the valley. That person sees, as it were, simultaneously the past, the present, and the future of people walking along the road. A similar type of simultaneity was also defended by Wolfhart Pannenberg (1928–). Within omniscience one distinguishes a *scientia necessaria* (knowledge about God and about all possibilities) and a *scientia libera sive visionis* (complete knowledge or vision of actual reality in past, present, and future).

One conceptual difficulty of this interpretation of divine omniscience concerns its epistemological range: Is experiential or existential knowing possible for an intuitively knowing God? Another difficulty: Is knowledge of a nonexistent future real knowledge? Knowledge of the future is conceivable in an atemporal ontology, but that makes time-experiences illusionary. Apart from that, such a reality seems to be determined because of the co-existence of past, present, and future. How is human freedom related to God's eternal knowledge of it? Is human moral responsibility in such a reality a real option? So-called incompatibilists will answer in the negative: Absolute timeless divine foreknowledge is incompatible with human freedom. Therefore, some of them argue against absolute foreknowledge whereas others use it against human freedom. Compatibilists will answer in the affirmative: Human freedom and absolute foreknowledge are compatible. Some of them will argue that there are alternative interpretations of a *scientia media* (middle or consequent knowledge about what each creature would freely do in any possible situation) that might solve the problem of compatibility.

See also GOD

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LUCO J. VAN DEN BROM

ONTOLOGICAL ARGUMENT

Ontological arguments attempt to establish the existence of God by relying on one's concept of God, or the definition of the word *God,* without involving truths known through experience. Such arguments have had many proponents in the history of philosophy, notably Anselm of Canterbury (1033/34–1109) and René Descartes (1596–1650), as well as many detractors, including Thomas Aquinas (c. 1225–1274) and Immanuel Kant (1724–1804). Today ontological arguments are widely considered flawed, but exactly what is wrong with them remains a matter of controversy.

The *locus classicus* is chapter two of Anselm's *Proslogion,* where he calls attention to the idea of a being greater (more excellent) than any other conceivable being, that is, the idea of a maximally great being. Anselm maintains that even those who reject the existence of a maximally great being still possess the concept of one. Now—and this is the key premise—if there were no maximally great being, one could conceive of something even greater than it by conceiving of a maximally great being *that exists.* But it involves a contradiction to say that one can conceive of a being greater than a maximally great being. Hence, absurdity results from the supposition that God does not exist.

A common response focuses on an assumption behind the key premise, namely that something can be greater than another thing simply by virtue of existence. What is one to make of this thesis? It appears to be false for the simple reason that a comparison of greatness requires (at least) two *existing* things to compare. But the proponent of the argument might reply that one can compare things without assuming their existence—for example, the strength of Achilles and Hector. It is therefore important how this is done. Perhaps it simply involves a comparison of the relevant concepts. Then the key premise means, "If nothing in existence corresponded to one's concept of God, one could generate a superior concept by representing God as existing." But this seems false; one's initial concept, which failed to correspond to anything, might well have been the concept of God-as-existing.

More plausibly, to compare the greatness of two things without assuming that they exist is to ask which of them would be greater if both were to exist. But if to compare the greatness of two things they must both be thought of as existing, existence itself cannot be considered a respect in which they differ in greatness. Thus, as Immanuel Kant argued, existence is not a "perfection"; it is not a property that can contribute to something's greatness.

There are at least two ways to avoid this objection: (1) one could claim that some objects of thought possess a mode of being distinct from existence; or (2) one could alter the argument to build on the claim that *necessary* existence (rather than *mere* existence) is a perfection.

According to the first approach, there are such things as, for example, unicorns; they just do not exist. They are abstract objects of thought that lack spatiotemporal location and causal powers. Thus, one could really consider the "greater than" relation to involve two entities even if one or both of those entities do not exist. And one can treat existence as a property that enhances the greatness of something after all.

Another general objection to the ontological argument, however, causes problems for this approach. Could one not use reasoning similar to Anselm's in order to establish the existence of all kinds of things? Consider the idea of an island greater than any other island that can be conceived. Since such an island can be the object of one's thoughts, it must (on this view) be an abstract entity, even if it lacks existence. If it does lack existence, however, one could think of a greater island, namely an island that also exists. So a maximally great island must exist. But (unfortunately) the greatest conceivable island does not exist, so the argument form cannot be sound. This parody was conceived by the monk Gaunilo, a contemporary of Anselm's.

Replying to Gaunilo's parody, Anselm insisted that the argument form can only establish the existence of that which is greatest or most perfect *simpliciter,* and not the most perfect island or bluebird. The argument form, he suggests, will only work if the concept one begins with is that of a being that could not have failed to exist. But all islands and other material objects are the sorts of things that could be destroyed. A rejoinder might alter the parody to involve the idea of a spiritual entity with almost every perfection (e.g., a godlike being lacking only a certain amount of knowledge but nevertheless a necessary being).

Inspired by passages in Anselm that suggest a different kind of ontological argument, some proponents avoid the above dispute by focusing on God's necessary existence rather than on God's existence. This is the approach of Charles Hartshorne, Norman Malcolm, and Alvin Plantinga. For anything to count as God, they argue, it would have to be absolutely perfect. But anything that exists and yet might not have existed is thereby deficient in some way. So if God exists, God exists necessarily; it could never be that God just happens to exist. Now, one can think of a necessary being as something that exists according to all the ways the world might have been, or "possible worlds." So either God exists in every possible world or in none. But this means that, so long as it is possible that God exists, God actually exists; after all, the way things actually are is one of the ways things can be. Thus, the argument forces a dilemma between the necessity of God's existence and its impossibility.

The key question, then, is whether the existence of God (conceived of as a necessary being) is even possible. Certain philosophers have held that possibility is something conceptual, and that unless the concept of God is somehow incoherent, the existence of God is possible. Thus Charles

Hartshorne has argued that either God exists or else the term *God* is meaningless or self-contradictory. And on the face of it, the existence of God certainly does not appear to be incoherent, like the existence of a round square. It seems perfectly conceivable.

The trouble is that the nonexistence of God also seems conceivable. And if it were even possible—assuming that God is by definition a necessary being—it would follow that God does not exist. So it would appear that the link between conceivability and possibility in this case is tenuous. And philosophers today are widely in agreement that states of affairs may be metaphysically impossible without involving any absurdity that is accessible to a priori reflection. So it is hard to see how one can assess the possibility of God's existence unless one has reason to affirm or deny God's actual existence, which is the point at issue.

See also COSMOLOGICAL ARGUMENT; GOD, EXISTENCE OF

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DAVID MANLEY

ONTOLOGY

Ontology is the study of being, insofar as being is possessed by any kind of entity. Although the term *ontologia* derives from the early seventeenth century, ontology is as old as philosophy itself. While German mathematician and philosopher Christian Wolff (1679-1754) identified ontology with *metaphysica generalis* (inquiry into the general categories of being), the relationship between ontology and metaphysics has become less precise. Some believe the two synonymous; others hold that while metaphysics deals with the nature and structure of all *possible* being, ontology only concerns actually *existing* beings. Ontological questions permeate the science-religion conversation; for example, what is the ontological status of the divine, and of putative emergent properties (e.g., the mental)?

See also METAPHYSICS

DENNIS BIELFELDT

OPEN UNIVERSE

Within standard Big Bang cosmology the universe is considered to be "open" if it contains insufficient matter to produce enough gravitational pull to stop its present expansion. In so-called Friedmann type universes (from mathematician Alexander Friedmann's [1888–1925] calculations based on Einstein's theory of relativity) only three universes are possible: the closed, in which the universe has sufficient matter to cause its recollapse; the flat, in which the universe will only just avoid recollapse; and the open. For the purposes of scientific eschatology, flat and open universe models lead to similar ends, namely, an eternally expanding universe that finally ends in heat death when all energy sources are exhausted. While most cosmologists are pessimistic about the long-term prospects for life and intelligence in such a universe, some hope has been offered. The problem and possibility of life in the remote future within an open universe was treated by Freeman Dyson (b. 1923) in 1989. For life to exist indefinitely in such a universe, however, Dyson suggests that it must either hibernate for very long periods or evolve into large clouds of dust carrying positive and negative charges that enable it to organize and communicate via electromagnetic forces. This vision is far removed from the heavenly existence postulated by many traditional religions.

See also CLOSED UNIVERSE; COSMOLOGY, PHYSICAL ASPECTS

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MARK WORTHING

ORDER

In most religions the world is believed to be an embodiment of divine wisdom. Paradoxically, the divine is both present (immanent) and absent (transcendent). This paradox is expressed in a hierarchy of degrees of manifestation of divine wisdom, each representing a kind of order. Further, both the natural and the moral order are seen as normative. In the Abrahamic religions order is created and, therefore, dependent on the creator. Since order is a manifestation of divine wisdom, it reveals knowledge about God. Accordingly, the created order has been seen as a unity in diversity, a machine, a work of art, or an embodiment of reason, beauty, and goodness. Disorder invaded the natural and the moral order, which require re-creation. In the Gnostic religions, however, disorder originates from an evil creator who battles a good redeemer. In response, the early Christian theologian Irenaeus (c. 130–200) emphasized that the creator and redeemer are one God who controls disorder and restores order. John Calvin (1509–1564) added that the created order required constant divine support to protect it from collapse into disorder: It could not exist independently. In contrast, for the theologian John Haught (1942–), disorder is the price God paid to grant freedom and independence to the created order.

Kinds and hierarchy of order

Science, philosophy, and theology recognize different kinds of order, as well as an order for the different kinds of order:

(1) One kind of inanimate order concerns energy. It refers to interactions with irreversible cause and effect relationships (heat melts ice).

(2) The order of life involves complexity. A complex sequence of molecules (DNA) carries information, which is transmitted from parent to offspring in a causal genetic relation. Mutations are not directed by the environment or the needs of the organism. This random order of mutation and the nonrandom order of natural selection produces organisms that are adapted to their environment.

(3) The order of reasoning involves the self-reflective awareness of norms for making distinctions, such as the principle of identity and the principle of the excluded third, as well as norms for correct arguments.

(4) The spiritual order concerns one's relationship with the divine. It is often characterized as a form of love, as it is, for example, in Hinduism and in the Abrahamic religions. These kinds of order represent ways in which entities exist, as well as ways in which people experience them.

The kinds of order are integrated in a hierarchy of order. In living things, the order of complexity, such as that of DNA, requires the order of energy with its chemical interactions, but chemical interactions do not require the complexity of living things. In a scientific explanation, the order of reasoning requires the order of sensation, but sensation does not require knowledge. In religious faith, the spiritual order of love requires the order of reasoning with its distinctions, but not vice versa. Thus, any kind of order is a necessary but insufficient condition for a higher kind of order. The complete hierarchy of kinds of order is found in persons and includes number, space, motion, interaction, life, sensation, perception, reasoning, human relations, lingual expression, legality, morality, and spirituality. Further, the order of life is not reducible to the order of energy. Nor can reasoning be reduced to sensation, or love to reasoning.

Entities can be ranked according to their highest kind of order, producing a hierarchy of entities. Chemical reactions exchange energy, but they do not transmit information to offspring. Plants transmit information to offspring, but they do not have knowledge. Animals have knowledge, but no spirituality as people do. Thus, the highest order in which entities function is the order of energy for chemical reactions, the order of life for plants, the order of knowledge for animals, and the order of love for people.

Order in the science-religion dialogue

One necessary condition for a mutual relevance of scientific and religious perspectives on order is that it is interpreted as divine action in the world. This, however, is not sufficient because a religiously interpreted order can be explored in science apart from its religious meaning (methodological atheism). Or the creator may be seen as utterly other than the created order so that what is known about nature is irrelevant for what could be known about God and vice versa (Eastern Orthodoxy, voluntarism in Western Christianity and Islam).

One sufficient condition for mutual relevance is that religious views of natural order serve in science as presupposition, sanction, motive, criterion for theory choice, criterion for the choice of kinds of explanation (regulative principle), or as part of explanations (constitutive principle), and vice versa. The rejection by Albert Einstein (1879–1955) of the probabilistic view of quantum physics was regulated by his belief that "God does not play dice." In reverse, the switch from a fixed to an evolving order of nature has motivated the development of evolutionary theologies and has constituted new conceptions of God, creation, divine grace, divine power, and redemption. For instance, instead of conceiving of divine power as a coercive force it is seen as persuasive love because divine love implies giving the universe the freedom to produce itself. Here, the biological idea of random mutation has been translated into the religious idea of a nature free from divine coercion.

A different type of sufficient condition is met in reductionism. In it a scientific definition of order is generalized into a metaphysical ideal of order. For instance, the empiricists as well as the neo-positivists reduced the cognitive order to the order of sensation. Since God cannot be known by sensation, knowledge of God is not possible and religion is reduced to belief without grounds in knowledge. This places knowledge and belief in different categories preventing a cognitive relationship between them. Similarly, biologist Edward O. Wilson (1929–) replaced a spiritual description of God as a being independent of matter with a naturalistic description: God is nothing but an objectification of the imagination. This was his way of including God in a kind of order that science can deal with by gathering empirical evidence. By redescribing God, sociobiology changed the content of religious belief and theology.

A third kind of sufficient condition is satisfied when a reduced view of order functions as religion (scientism). Biology functioned as (anti-)religion when biologists Jacques Monod (1910–1976) and Richard Dawkins (1941–) interpreted the randomness of mutations to mean that there is neither God nor purpose or when Wilson wrote that scientific materialism and evolutionism are his substitute religion in which the purpose of life is to promote evolutionary progress. This substitute religion motivated his re-description of God and, thereby, constituted the content of sociobiological explanations of religion. Here, science as a substitute religion influences religion.

See also HIERARCHY; NATURE

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ORIGINAL SIN

See EVIL AND SUFFERING; FALL; SIN

ORIGIN OF LIFE

See LIFE, ORIGINS OF

ORIGIN OF UNIVERSE

See BIG BANG THEORY; COSMOLOGY; COSMOLOGY, PHYSICAL ASPECTS; T = 0

ORTHODOXY, EASTERN

See CHRISTIANITY, ORTHODOX, ISSUES IN SCIENCE AND RELIGION

P

PAIN

See EVIL AND SUFFERING; THEODICY

PALEOANTHROPOLOGY

Paleoanthropology is an umbrella term for the diverse group of sciences contributing to the knowledge of human evolution, generally interpreted to include not only studies of extinct (and, in evolutionary contexts, living) humans and their exclusive ancestors and relatives, but also of the wider biological framework within which the hominid family exists. At the core of paleoanthropology are the paleontologists who study human fossils, and the archaeologists who investigate the behavioral record of ancient humans. They are complemented by paleoenvironmentalists, taphonomists, dating specialists, functional anatomists, paleodemographers, molecular geneticists, and a host of others who contribute to producing as well-rounded a picture as possible of the background from which humans emerged.

See also EVOLUTION, HUMAN; PALEONTOLOGY

IAN TATTERSALL

PALEONTOLOGY

Paleontology is the branch of science devoted to the understanding of past life as revealed by the fossil record. Normally, when an organism dies, its physical remains are scattered and destroyed by the elements in a short span of time. Such elements include not only wind, weather, and decay, but also water and the activities of carnivores and scavengers of many kinds. Occasionally, however, bony remains (and, very exceptionally, some soft tissues) lying on the surface or in superficial cavities may be covered by accumulating sediments (most often river or lake muds in the case of terrestrial organisms, and sea-bottom particulates in that of marine forms) before they are totally destroyed. Among the remains that escape destruction, complete articulated skeletons are extremely rare; more commonly preserved are individual bones and teeth, often broken. Unless the enclosing sediments are chemically hostile, or become melted by heat from the Earth's interior or pressure from above, bones thus incorporated into the accumulating sediment pile can survive more or less indefinitely, though their distortion due to local Earth movements is not uncommon. As water carries minerals in solution through both the sediments and the contained animal or plant remains, the organic constituents of those remnants become replaced by minerals, in a process most often known as mineralization. If erosion of the enclosing sediment pile subsequently sets in, the now-fossilized remains may become exposed once more at the Earth's surface, where they are yet again subject to the forces of natural destruction. However, for a brief period they are also available to be collected by human beings, who have been picking up unusual re-exposed objects for the last few hundred thousand years, at least.

Fossils are found all over the world, and are a vast storehouse of information about past life.

Those who professionally find fossils and extract such information from them are known as *paleontologists.* From the very beginning, paleontology has been integral to the study of Earth history, which began with attempts to order the sedimentary rocks, laid down by water and wind, which contain fossils. The other grand categories of rocks exposed on the Earth's surface include igneous rocks (extruded from Earth's molten core by volcanoes and by the physical rising through the solid crust of lighter rocks such as granite), and metamorphic rocks, which are sedimentary rocks that have been recrystallized by pressure and heat. Volcanic rocks are particularly helpful in dating the ages of various events in Earth history because reliable techniques exist by which to measure the time that has elapsed since they last cooled. These techniques depend on the phenomenon of radioactivity, by which unstable forms of certain elements "decay" to stable states at known rates. Volcanic rocks do not contain fossils themselves (unless you count as fossils such things as the vacuities in the shape of human bodies found at Pompeii, or the ancient hominid footprints at Laetoli), but they represent single points in time and are often interleaved among sedimentary fossil-bearing layers, which can be dated by reference to them.

Early history

The basic principles of the study of sedimentary rocks were established by the Danish-born naturalist and physician Nicolaus Steno (1638–1686) in the mid seventeenth century. These principles state that all stratified sedimentary rocks—however distorted they may subsequently have become—started life as horizontal bands of sediments and that they were laid down in sequence, with the oldest layers at the bottom and the youngest at the top. Such layering is usually readily visible in local sedimentary basins, but there is a problem in correlating the strata that are exposed in different basins and geographical areas. This is the context within which fossils entered the picture. The fossil record clearly shows that past time has been characterized by a long succession of distinctive *biotas,* or communities of organisms; it was the resulting diagnostic assemblages of fossils that were seized upon by early stratigraphers as the key to ordering regionally exposed rocks into their temporal sequences.

During the early years of the nineteenth century, the engineer and geologist William Smith (1769–1839) demonstrated in England that sedimentary units could be identified by their distinctive fossil content. At about the same time in France, naturalist Georges Cuvier (1769–1832) worked out the sequence of sedimentary units in the Paris Basin using fossil terrestrial vertebrates as markers, and showed that many large animals had no living counterparts. In doing the latter, Cuvier made extinction a reality to be contended with. And he went farther, showing that as the rocks became younger they contained faunas steadily more similar to those of today. He concluded that this pattern revealed an advancing complexity of life, but he was unable to find gradations among the various faunas preserved in the Paris Basin (where stratigraphic discontinuities are in fact rife, as they are in most terrestrial situations). Instead, he found that distinctive faunas were replaced by other distinctive fossil associations. This suggested to Cuvier that a series of catastrophes had wiped out successive faunas, which were re-created anew after each extinction event. Popular opinion rapidly adopted the last such event as evidence of the Biblical deluge, and conveniently equated the earlier faunas with the biblical "days" of creation.

Thus, improbably, was paleontology born as a science. For several decades following the pioneering work of Cuvier and Smith, paleontologists labored within the confines of biblical constructs even as they gradually built up a robust picture of the Earth's sedimentary history based on an expanding fossil record. During this period the beginnings of specialization within paleontology began to appear, with today's division of the science into *vertebrate* and *invertebrate* branches emerging. The distinction is important, not simply because of the distinctiveness and the rapid swelling of the database in each branch, but because invertebrate paleontology came to be dominated by the study of marine organisms, just as vertebrate paleontology was dominated by terrestrial forms. Neither branch was (or is) exclusively focused on one side or the other of the marine-terrestrial dichotomy, but a subtle difference in outlook was almost inevitably introduced because the marine sedimentary record is much more continuous than its terrestrial equivalent, which is repeatedly interrupted by erosional cycles.

Paleontology and evolutionary ideas

By the time that Charles Darwin (1809–1882) published his epochal *On the Origin of Species* in 1859, the outline shape of the fossil record was fairly well established. Inconveniently well-established, in fact, as far as Darwin was concerned. For while Darwin favored an elegantly simple model of evolution as a more or less straight-line process involving gradual change in living populations from generation to generation under the guiding hand of natural selection, the fossil record itself showed a pattern of discontinuities among *taxa* (a generalized term given to taxonomic units at any rank: species, genera, and more inclusive groupings such as families and orders). There was much early debate over the application of Darwinian ideas to the fossil record. Some scientists, such as the eminent Victorian comparative anatomist Richard Owen (1804–1892), who appropriated the study of the remarkable fossil reptile bones discovered by Gideon Mantell (1790–1852) in the 1820s (and who coined the term *dinosaur*), reacted negatively to Darwin's publication. Owen preferred to see the fossil record as evidence of the unfolding of a divine plan, and clung throughout his life to an essentialist view of species as fixed and unchanging. Others, such as the brash Thomas Henry Huxley (1825–1895), took up the cudgels on Darwin's side, most famously in his debate with Bishop Samuel Wilberforce (1805–1873) in Oxford on June 30, 1860. Huxley supported Darwin's view of fossils as witnesses to a process of gradual transformation of organisms over time—although, significantly, he never managed to place the newly-discovered Neanderthal fossil into this perspective, preferring to interpret it as a lowly form of modern human.

Interestingly, following a scandalized initial reaction to his evolutionary ideas, Darwin's central tenet of "descent with modification," whereby all life forms are related by descent from a common ancestor, became quite rapidly accepted by scientists and public alike. What was not so readily accepted was the mechanism of *natural selection,* which involves the gradual modification of population gene frequencies over long periods of time due to the greater reproductive success of *fitter* individuals, those best adapted to prevailing environments. Indeed, natural selection did not assume its current central place in paleontology and other branches of evolutionary biology until the second quarter of the twentieth century, when the *Evolutionary Synthesis* took biology by storm. The product of agreement among influential geneticists, paleontologists, and systematists, the Synthesis eventually succeeded in reducing virtually all evolutionary phenomena to generation-by-generation changes in gene frequencies. This notion emphasized the linear, transformational, dimension of evolution at the expense of the histories of taxa, and it encouraged paleontologists to ignore the discontinuities in the fossil record that Darwin had been aware of, but had ascribed to the record's incompleteness.

It was not until the 1970s that paleontologists started to realize that perhaps the gaps in the fossil record were actually revealing something after all. Thus was born the notion of *punctuated equilibria* (long periods of stasis interrupted by brief bursts of change), which was presented as an alternative to the *phyletic gradualism* preached by the Synthesis. Paleontologists in general began to realize that the Synthesis, elegant though its simplicities might have been, was incomplete as an explanatory framework for all of the evolutionary phenomena evoked by the fossil record. It turned out, indeed, that although natural selection undoubtedly plays a role in the differentiation of species and in their accommodation to local environments, many other influences enter the evolutionary equation. These include *speciation,* the set of mechanisms by which new species come about, and *competition* among closely and more distantly related species, which involves *extinction* as a regular event. All of this occurs, moreover, within a context of constantly fluctuating environmental conditions. Modern paleontologists are hence much more acutely aware than their predecessors were of the complexities of the evolutionary process and of the roles played in it by competing taxa, as well as by competing individuals.

Hypothesis formation in paleontology

For many years paleontologists pursued their work—of sorting out the relationships among the myriad life forms represented in the fossil record—largely by intuition and the assessment of overall resemblance. Admittedly, this process got them a long way in sketching the outlines of the tree of life, but it did lead to some anomalies. Thus while it may appear counterintuitive to claim that lungfishes are more closely related to cows than to salmon, in terms of ancestry and descent this claim is demonstrably true. Paleontology was thus revolutionized during the 1970s by the widespread introduction of *cladistics,* an approach to comparative biology that provided an explicit recipe for recognizing relationships among taxa. In a nutshell, cladistics argues that only the common possession of derived characters, those inherited from an immediate ancestral taxon, is useful in deducing relationships among taxa. The common possession of primitive attributes, those inherited from more remote common ancestors, shows only that two taxa belong to the wider group descended from that ancestor. Thus having a spine shows simply that you belong to the large taxon of vertebrates, while having three bones in the middle ear indicates that you are a mammal, a member of a taxon that is nested inside that group. The distribution of derived characters within a group is summarized in a branching diagram known as a *cladogram,* which in its simplest form states nothing more than that "taxon *A* and taxon *B* are more closely related by common ancestry than either is to related taxon *C*." Cladograms are the only statements in systematics that are truly testable.

More elaborate is the *evolutionary tree,* which adds ancestry and descent as well as time to the mix. Trees are more interesting than cladograms, but cannot be tested since the age of fossils has no direct connection to their relationships, and because in theory an ancestor has to be primitive in all respects relative to its descendant, in which case there is nothing to link them. Yet more complex (and more interesting) is the *evolutionary scenario,* in which paleontologists add everything they know about function, environment, adaptation, and so forth to the information present in the tree. Competing scenarios are comparable only on the basis of their plausibility, which makes them inherently unscientific; yet their plausibility can be reasonably objectively judged if they are based on specifically stated cladograms and trees. Scenarios are constructed using a bewildering variety of types of information derived from many different sciences. Paleontologists take into account information derived from *paleoclimatology* (the study of past climates), *taphonomy* (the science of what happens to organic remains after death), *sedimentology* (environments in which fossils were deposited), *stratigraphy* (in the broadest sense, the sequence and relationships of rock strata, and their dating by a host of means), and *functional anatomy* (the study of the morphology of fossil forms, and how they may have functioned in life), to name but a few of the areas that contribute to the most complete understanding possible of the lives, environments, and relationships of fossil species. *Molecular genetics* has also begun to contribute to our knowledge of affinities among extinct species, and even newer technologies are on the way.

Paleontology in a wider context

Since about 1970, then, paleontology has vastly refined its abilities to teach us about our past and about the broader biological context from which our remarkable species has emerged. Literally, paleontology has played and continues to play a central role in establishing our own place in nature. And the lesson is a humbling one. The living world of today is mind-bogglingly diverse and marvelous indeed, heedless though so many of us are of its welfare. But looking around ourselves today we see only a single slice of time; and when we add the paleontological dimension we can at last begin to glimpse the truly extraordinary richness and majesty of the organic context—creation, if you will—of which we form part.

This recognition of the vastness of nature in time as well as in space has had a profound impact. Since medieval times and probably long before, people in the Western tradition had viewed *Homo sapiens* as the center of earthly creation, around which all else revolved. But paleontology, especially in concert with the more recent revelations of cosmology, has demonstrated that our species is in fact an infinitesimal part of an enormous and still-enlarging universe. Among many members of our egotistical species, the tendency has been to ignore this uncomfortable fact. But it is nonetheless a fact to be faced, and some theologians have sought to reconcile the findings of paleontology with the traditions of Christian theology. The best-known of these was the Jesuit Pierre Teilhard de Chardin (1881–1955), a practicing geologist and paleontologist, whose posthumously published *The Phenomenon of Man* had a particularly broad impact. Teilhard viewed the process through which humanity emerged in teleological terms, envisioning the appearance of human consciousness as the outcome of directed change from a more generalized state, in pursuit of an ultimate union with the "Omega." This latter was taken by many to represent a "cosmic Christ," as the biologist Julian Huxley (1887–1975) put it. Teilhard's arguments are often obscure, but his wide following bears witness to the profound urge that exists among so many to incorporate the perspectives of paleontology into a wider worldview.

See also DARWIN, CHARLES; EVOLUTION, HUMAN; GRADUALISM; LIFE, ORIGINS OF; PALEOANTHROPOLOGY; PUNCTUATED EQUILIBRIUM; TEILHARD DE CHARDIN, PIERRE

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PANENTHEISM

The term *panentheism* (from the Greek) literally means "all (is) in God." As a concept of God, panentheism attempts to do justice both to divine transcendence (God is beyond or more than the world) and divine immanence (God is in the world). Panentheism maintains that the world is in God, included in the divine life, but that God's reality is not reducible to nor exhausted by the reality of the individuals or the structures of the universe or of the universe as a whole. Thus God is all-inclusive or all-encompassing with respect to being.

Strictly construed this entails that all divine relations are internal relations, that is, relations between God as integrated whole and the creatures as included parts. For panentheism then, while the universe is part of God, God and the universe do not form an undifferentiated whole. Panentheism draws definite distinctions between God as the including whole and the nondivine parts of the universe considered in themselves. Certain properties of divinity, such as *aseity* (self-existence) or necessary existence and the all-encompassing attributes of omnipresence (everywhere present), omniscience (all-knowing), and omnipotence (all power or all-powerful) apply to God but definitely not to individual creatures or to the universe itself. (Note though that process forms of panentheism find the notion of divine omnipotence problematic.)

Another important distinction drawn between God and creatures concerns mutual freedom. Panentheism upholds indeterminism: Spontaneity and free will in the universe mean that antecedent causes do not fully determine present events and actions, so the future is not fully predictable or foreknown, even by God; creatures have real choices. In summary, while God is not an individual simply distinct from the nondivine individuals, in the way, for example, that one human being is distinct from another, neither is God to be equated with the universe or its constituents.

Panentheism as alternative

In construing divine transcendence and immanence as above, panentheism mediates between deism and certain forms of traditional theism on the one hand and pantheism on the other hand, attempting to avoid pitfalls of both. Deism, as developed in the European Enlightenment of the seventeenth and eighteenth centuries, holds that God created the world to operate according to natural laws but is uninvolved in its destiny. The God posited by traditional theism is not as separate from the universe as is in deism; however, panentheists judge what they call *classical theism* to be equally inadequate. Classical theism, in affirming certain divine attributes stemming from ancient Greek philosophy—immutability (unchangeability), impassibility (to be unaffected by another), and eternity (in the sense of strict timelessness)—does not permit God to be in genuine relation to the world.

The term *pantheism* literally means "all (is) God." That is, everything at least in its true essence is divine. Clearly panentheism has affinities with pantheism. American Charles Hartshorne (1897–2000), the principle theological interpreter and developer of process philosophy, at first labeled his concept of God "The New Pantheism." The trajectory of German idealism produced both pantheists and panentheists. One could say that panentheism attempts to get as close to pantheism as possible in stressing the intimate relationship between God and nature, while still maintaining clear distinctions between them. A key difference is that pantheism tends to a (quasi) materialistic or (quasi) substantialistic understanding of God: Entities in the world share the divine essence or substance to a greater or lesser degree. Therefore, any distinction between God as a whole and the constituents of the universe is a matter of degree rather than of kind. In addition, since everything is a mode or attribute of God, pantheism typically denies indeterminate freedom.

The metaphor or analogy of the world as the body of God is popular among panentheists. Hartshorne compares the God-world relationship to that between a person's mind and the cells of its body. Arthur Peacocke (1924–), a key figure in the science and religion dialogue, speaks approvingly of the feminine, womb imagery that panentheism encourages: As with a fetus in its mother, creation is within God. American Christian theologian Sallie McFague (1933–) has been the principal developer of the metaphor of world as body of God. British philosophical theologian Grace Jantzen (1948–), in drawing the connection between God and world so tightly as to jettison indeterminate freedom, offers a pantheistic version of the metaphor.

Some connections with science

Panentheism offers diverse advantages for those interested in the intersection of science and religion. Alfred North Whitehead (1861–1947), in his role as a philosopher of science, and others have observed that the dominant model for the natural world moved from mechanism to organism during the nineteenth century. Panentheism offers an organistic understanding of the God-world relation in contrast to deism's mechanistic understanding. Like deism, panentheism offers a concept of God where natural laws or processes are respected, where God refrains from interventions that overturn nature. The crucial difference is that panentheism posits a God intimately involved, continuously interacting, with the world.

Panentheism's intimate connection of God with a world in time entails a God who in some sense or dimension is also temporal. As the trajectory of modern science—from the Newtonian mechanics of the Enlightenment to evolution to Albert Einstein's theory of relativity—has put an exclamation point on the temporal nature of reality, panentheism offers a consonant concept of the divine.

As indicated above, creaturely spontaneity and indeterminate freedom are crucial for panentheism in its distinction of God from creation. Both quantum mechanics, in stating that the motions of subatomic particles are probabilistic rather than determinable from known antecedent conditions, and chaos theory, in demonstrating the unpredictability of future events, provide openings for panentheists and other supporters of indeterminacy. In particular, Peacocke, a British physical chemist, Anglican priest, and panentheistic theologian, applauds panentheism's picture of a God who is continuously creative in relation to an open universe. It must be noted, though, that no consensus exists among scientists that quantum indeterminacy or, even less, chaos theory unpredictability entail any ultimate indeterminacy in the universe.

Avoiding violation of natural processes is not only a concern of panentheists but of other theologians involved in the science and religion dialogue, including Americans Thomas F. Tracy and Nancey Murphy. It may seem that such thinkers must renounce any traditional Christian notion of special providence, namely, that God causes particular events in natural or human history (in contrast to general providence, that God determines the general laws or processes of the universe), however, this is not uniformly the case.

For example, in his later writings, Peacocke develops his notion of top-down causation, maintaining that divine action with respect to the universe not only upholds general laws or patterns but causes specific events. Whether such divine predetermination is compatible with indeterminate creaturely decisions and their chance interactions is a major difficulty for this viewpoint.

Murphy and Tracy purchase special providence by positing that God determines the probabilistic quantum movements of subatomic particles and that these in turn produce macro-effects that result in specific events. The virtue of this notion is that it contravenes no natural laws or regularities: The quantum events that God determines are within the scientifically permissible ranges of motion, and apparently no conceivable method exists for discerning God's causation on the quantum level. At the same time, this "invisibility" is problematic: That God ultimately causes a valued event (as opposed to, say, an event issuing in tremendous evil) appears to be a matter of blind faith, at least as far as physics is concerned. Other problems for this viewpoint are the speculative nature of the connection between quantum events and macro-effects and, for advocates of indeterminacy and openness, the denial that quantum events are ultimately indeterminate. More broadly, critics of the above approaches might judge them to be backdoor attempts to reintroduce too much transcendent or interventionist causation by God.

Panentheism's history

The term *panentheism* was coined by German idealist philosopher Carl Christian Friedrich Krause (1781–1832). As mentioned above, German idealism, with strong ties to nature romanticism, produced various panentheistic and pantheistic thinkers. The clearest and most fully developed panentheistic model was that of physicist, experimental psychologist, and philosopher Gustav Theodor Fechner (1801–1887). Earlier examples of panentheism or panentheistic tendencies include Western mysticism and Hindu *bhakti* (referring to devotion to a personal god) and its principal theologian Ramanuja (traditional dates, 1017–1137). These examples are not surprising, as mysticism generally softens the creator-creature distinction, while in India that distinction is not drawn as sharply as is typical in Western religions.

Various philosophers and theologians of the twentieth century have been labeled panentheists, including Nicolai Berdyaev, William Pepperell Montague, Paul Weiss, Karl Rahner, and John MacQuarrie. While the panentheistic affinities of these thinkers are undeniable, some failed to develop a clear panentheistic model, others promoted ideas contrary to basic premises of panentheism, while still others explicitly refused the label *panentheism* for their thought. Coming out of German idealism, American Paul Tillich (1886–1965), an exile from the Nazis, is regarded as one of the premier theologians of the twentieth century. Tillichians widely acknowledge his panentheism. His famous phrase, "God is not a being, but being-itself," has obvious panentheistic implications. Tillich, who claimed the phrase "eschatological pan-en-theism," was accused by some critics of pantheism, to which he would jokingly respond, "This pantheist is going to take a walk in his garden." Tillich's reluctance to disavow the attributes of divine immutability, impassibility, and eternity compromise his manifest panentheistic intentions, according to American theologian David Nikkel (1952–).

The fullest explicit development of panentheism in the twentieth century came from process thought. Whitehead, a British mathematical physicist and philosopher, originated process philosophy, its theism developed and to some extent modified by Hartshorne. For process thought, reality at its depth is not static being but rather a process of becoming. God is not an exception to, but the highest exemplar of, this ultimate or metaphysical principle. As did Fechner, process thought advocates *panpsychism,* that all integrated entities of the universe possess some degree of sentience or feeling. The fundamental unit of reality for process philosophy is an occasion of experience. God, in the consequent nature for Whitehead or the concrete pole of divinity for Hartshorne, includes all past occasions of experience. Process panentheism emphasizes omniscience and, to coin a word, *omnipathy* (all-feeling). God intimately knows all experience, is affected by, sympathizes with, all feelings. As Whitehead puts it, "God is the fellow sufferer who understands" (1928, p. 351). Whitehead purchases divine transcendence through the primordial nature, which is the reservoir of all possibility. Hartshorne purchases the same through the abstract pole of divinity, which refers to the changeless character of God, namely, that God will always lovingly know and integrate whatever experiences occur in the universe. If the world influences God as object of divine knowledge, God likewise influences the nondivine individuals as object of their awareness, as a lure providing preferences for their actions. To what extent the divine lure only persuades versus constrains decisions as the unavoidable object of awareness is debated by process theologians. What is beyond dispute is the rejection of omnipotence, if interpreted to mean God is all-powerful, which would overthrow indeterminate freedom.

Contemporary issues

McFague, mentioned earlier in relation to feminist divine imagery, has presented one of the most well-known models of panentheism in the late twentieth and early twenty-first centuries. Her development of metaphors for a God in intimate relation with the world enflesh and enhance the sense of the concept of panentheism. On the other hand, her doubts concerning what we can actually know about God pose a potential problem for her panentheism. McFague's minimal Christian theistic claim is that there is a power in the universe on the side of life that is, metaphorically speaking, personal. When McFague adds that this power is many rather than one, critics may question whether God in her concept or metaphor is sufficiently integrated to panentheistically include the universe; critics may question whether there is a difference of substance between her view and American Christian theologian Gordon Kaufman's serendipitous creativity, that *God* should refer to the cosmic and evolutionary forces that have resulted in life and human life rather than to any personal or agential reality. Contrast McFague's outlook to that of Tillich and Hartshorne, who maintained that God is "not less than conscious" or superconscious (while recognizing the anthropomorphic dangers of attributing conscious personhood to God).

Many theologians in the science and religion dialogue affirm some notion of God's sustaining creativity common to the Western religious traditions: Every aspect of every particular constituent of the universe is radically contingent, dependent upon divine power for its continued existence moment by moment. Process theism rejects such an understanding of divine power. Whitehead is clear that both divine and finite occasions of experience are manifestations of the ultimate metaphysical principle of creative synthesis, each such occasion possessing ultimate independence of being. Whitehead reasons that if God were upholding the very existence of occasions, then indeterminate freedom would be overridden and his panentheism would transmute into a pantheism. Christian process theologians, while often neglecting to acknowledge this Whiteheadian perspective on divine power, have not challenged it either. The question for panentheists who wish to retain a notion of divine sustaining activity is this: Can *omnipotence* be defined as "all power" rather than "all-powerful"? Can God panentheistically encompass all power by sustaining and thus empowering the existence of each creature, as an existence with indeterminate freedom? If such a concept is not self-contradictory, then one can avoid pantheism and affirm a notion of divine power more consonant with the all-inclusive logic of panentheism.

See also CHAOS THEORY; DEISM; DOWNWARD CAUSATION; EINSTEIN, ALBERT; GOD; NEWTON, ISAAC; PHYSICS, QUANTUM; PROCESS THOUGHT; PROVIDENCE; THEISM; WHITEHEAD, ALFRED NORTH

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DAVID H. NIKKEL

PANTHEISM

Derived from the Greek words *pan* (all) and *theos* (God), thus meaning "all is God," pantheism is the view that the universe or nature as a whole is divine. In relation to rival views, pantheism is defined as the doctrine that God is neither externally transcendent to the world, as in classical theism, nor immanently present within the world, as in panentheism, but rather is identical with the world.

As a religious position, pantheism holds that nature is imbued with value and worthy of respect, reverence, and awe. As a philosophical position, pantheism is the belief in an all-inclusive unity, variously formulated. Historically, the nature of the unity has been defined quite differently in Plotinus's "One," Baruch Spinoza's "Substance," Georg Wilhelm Friedrich Hegel's "Geist," and Charles Hartshorne's "All-Inclusive Totality." Due to ambiguities in the chief analogies used by philosophers (whole-part; mind-body) the line between pantheistic and panentheistic positions is often difficult to draw. In general, pantheism represents an alternative to the classical theistic notion of God in Western philosophy and theology, and has close counterparts in Taoism, Advaita Vedanta, and certain schools of Buddhism. It is also the *ism* closest in spirit to Native American religions.

Types of pantheism

Two broad types of pantheism may be distinguished: monistic pantheism and pluralistic pantheism. Examples of monistic pantheism are classical Spinozistic pantheism, which devalued the importance of dynamic and pluralistic categories, and Hindu forms of pantheism, which have relegated change and pluralism to the realm of the illusory and phenomenal. In addition, the romantic and idealistic types of pantheism that flourished in nineteenth-century England and America were generally monistic.

The pluralistic type of pantheism is found in William James's *A Pluralistic Universe* (1908) as a hypothesis that supersedes his earlier "piecemeal supernaturalism" in *The Varieties of Religious Experience* (1902). James's conception emphasizes the full reality of insistent particulars, embedded in a complex web of conjunctive and disjunctive relations in which manyness is as real as oneness. Religiously, pluralistic pantheism affirms that evil is genuine, the divine is finite, and salvation, in any sense, is an open question. Further exemplifications of pluralistic pantheism are found in a series of late twentieth-century movements, including James Lovelock's Gaia hypothesis that the earth behaves like a single entity, the deep ecology movement, the feminist spirituality movement, and the New Age movement. In 1990 American historian Catherine Albanese, canvassing diverse forms of pantheistic piety since the early republic, considered nature religion in America "alive and well, growing daily, and probably a strong suit for the century to come" (p. 198).

Challenges to pantheism

The chief challenge to pantheism, according to critics, is the difficulty of deriving a warrant for the criteria of human good. How is one to establish any priority in the ordering of values and commitments if nature as a whole is considered divine and known to contain evil as well as good, destruction as much as creation? In light of this concern, John Cobb and other process theologians recommend a fundamental distinction between creativity as the ultimate reality and God as the ultimate actuality. In this way, the divine character is identified only with the good. Other theologians, like David Tracy, view such a metaphysical distinction as dubious and point out that the denial of any identity between ultimate reality and the divine may foster the view that ultimate reality is not finally to be trusted as radically relational and self-manifesting (Tracy, p. 139). The pantheistic model is capable of countering both of these concerns. On the first point, pantheism underscores the blunt fact that the rain falls on the just and the unjust alike, whatever model of the divine one holds. Critics of pantheism observe that human efforts toward compassion and justice are frequently not reinforced by ultimate reality. Nature is often indifferent to human desires and deaf to moral urgencies. Pantheists say this is indicative of the remorselessness of things, not of the superiority of either the theistic or the panentheistic model. In the second place, by collapsing the distinction between creativity and the divine, pluralistic pantheism does identify the religious ultimate with the metaphysical ultimate, but this identification may or may not entail the further (Christian) specification of ultimate reality as radically relational and self-manifesting. Due to its extreme generality, the pantheistic model is susceptible to multiple specifications of various kinds, on lesser levels of generality as found within the more concrete symbols and images of the world's religious traditions.

For secularist critics, the most significant objection to pluralistic pantheism is the semantic question. Why call it "God" or divine? According to nineteenth-century German philosopher Arthur Schopenhauer, calling nature or the universe God does not explain anything, but only serves "to enrich our language with a superfluous synonym for the word 'world'" (p. 40). Pantheists are apt to concede this point but to urge attentiveness to nature's terrible beauty all the same. In the words of the early twentieth-century American poet Harriet Monroe, "Call the Force God and worship it at a million shrines, and it is no less sublime; call it Nature, and worship it in scientific gropings and discoveries, and it is no less divine. It goes its own way, asking no homage, answering no questions" (p. 454). Recoiling from anthropomorphic myth-making, modern pantheists like Monroe express astonishment over the way religious creeds impose a name and person-like traits upon the creative force animating the universe. Avoidance of personalistic imagery and preference for vague talk of a "force" in nature is characteristic of contemporary pantheism.

Science and religion

Without using the term pantheism, many people who are not traditionally religious acknowledge the feeling that nature is sacred. While panentheism is a theological construction, pantheism probably has more grass roots appeal among ordinary people, artists, and scientists. As the most important challenge that the sciences pose to traditional religion is their skepticism about the existence of "another world" not of human making or open to human inquiry, supernaturalism is less and less an option among scientifically educated populations. In the engagement of science and religion issues, the relevant religious alternatives tend to reduce either to pantheism or to panentheism. Astrophysicist Carl Sagan spoke for those who prefer a straightforward pantheistic orientation over what they regard as the equivocations of panentheism: "A religion, old or new, that stressed the magnificence of the universe as revealed by modern science, might be able to draw forth reserves of reverence and awe untapped by the conventional faiths. Sooner or later, such a religion will emerge" (p. 52).

See also CREATION; DEEP ECOLOGY; FEMINIST COSMOLOGY; GAIA HYPOTHESIS; GOD; NATURE; SUPERNATURALISM; THEODICY

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NANCY FRANKENBERRY

PARADIGMS

The word *paradigm* comes from the Greek *paradeigma*: evidence, example, pattern, model, archetype. In linguistics, a paradigm provides an example of a conjugation or a declension. In philosophy, its meanings include an archetype, a standard of measurement, a typical case or suggestive example, and a dominating scientific orientation. The term *paradigm* is frequently used in the social sciences. In popular understanding, *paradigm* often simply means a collection of ideas, a cluster of theories, models or actions representing a guiding idea, or a conceptual framework.

The concept of paradigm since Thomas S. Kuhn

Thomas S. Kuhn's seminal work *The Structure of Scientific Revolutions* (1962) initiated intense discussions on the concept of paradigm, making the word *paradigm* part of the general intellectual discourse, though not always in the sense intended by Kuhn. According to one of the definitions given by Kuhn, paradigms are "universally recognized scientific achievements that for a time provide model problems and solutions to a community of practitioners" (p. x). A paradigm consists of a group of fundamental assumptions forming a shared framework that provides the scholar with instruction on what to view as issues of inquiry and how to deal with these issues. Hence, a paradigm works as a criterion for choosing problems that, as long as the paradigm is taken for granted, can be assumed to have a solution. Paradigms structure observation and define reality. Kuhn's perspective is historical: Preparadigmatic periods in science are followed by a time where a valid paradigm allows "normal science" (to use Kuhn's terminology) to take place. Under the conditions of normal science and its "strong network of commitments—conceptual, theoretical, instrumental and methodological" (p. 42), the community of researchers concentrates on the routine activity of "puzzle-solving" without testing the paradigm itself. However, an increasing number of observed anomalies leads to a crisis and eventually to a revolution and to the establishment of a new paradigm that is incommensurable with the old one. A paradigm shift has traits of a conversion. New candidates for paradigms are often presented by young scientists or scholars who are new to the field.

Kuhn's book created enough interest to make it a classic. Criticisms targeted the vagueness of his concept of paradigm both in definition and in use, the alleged incommensurability of the old and the new paradigm, and the notion of revolution as a description of development in science. Kuhn was charged with subjectivity, irrationality and relativism. The change of paradigm, which Kuhn described as "the selection by conflict within the scientific community of the fittest way to practice future science" resulting in "an increase in articulation and specialization" (p. 172), was said to belong to the realm of the social psychology of discovery rather than to the philosophy of science because the change follows values rather than formal rules. Kuhn's overstatement of revolution at the expense of the cumulative aspects of development in science and his emphasis on the consecutive at the expense of the simultaneous were modified to allow for the coexistence and even the interaction of different paradigms. Kuhn himself specified his notion of paradigm in two ways: a broad sense, also called a disciplinary matrix, which includes all the components of scientific consensus; and a narrow sense, which denotes exemplary solutions to problems. A paradigm has both descriptive and prescriptive functions, and it implies commitment by those who work in and under it.

Kuhn's concept of paradigm both in its initial and its modified shape has contributed to a number of achievements. The concept highlighted the historical situatedness of scientific research and the role of consensus in rationality. It lifted up the interplay of scientific and nonscientific components in the development of science. It focused on the ambiguity of commitment as that which can both undercut rationality and make scientific work successful. It acknowledged the circularity of abstracting data into a paradigm that informs the selection and interpretation of new data. Thus it contributed to fostering an interest in the sociology of scientific knowledge and in the hermeneutics of holistic nonuniversalist rationality. In the philosophy of science, the concept of paradigm has been followed by alternative concepts, such as *competing research programs* (Imre Lakatos) and *research traditions* (Larry Laudan).

The concept of paradigm in science and religion

The exploration of the concept of paradigm has had an impact on the relation between science and religion. The study has broadened the concept of rationality and affirmed its complexity and contextuality. It has nourished the discussion of the translatability of various discourses. It has also inspired a process of paradigm critique that questions the self-assuring power of paradigms and calls for an examination of the role of race, gender, culture, and political and economic power in the process of forming guiding ideas. In *Myths, Models, and Paradigms* (1974) and *Religion and Science* (1997), Ian G. Barbour uses the central features of the Kuhnian paradigm to argue that some of the same spirit of inquiry found in science also applies to religion: Religious experiences depend on a paradigmatic interpretive framework, religious paradigms are highly resistant to falsification, and no univocal rules exist for the choice between religious paradigms. These analogies presuppose a flexible definition of paradigm communities and of continuities versus discontinuities in paradigm shifts. Referring to paradigms as universal phenomena that provide comprehensive contexts for interpretation, Sallie McFague demonstrated in *Metaphorical Theology* (1982) that metaphorical thinking is basic to human understanding of the world. In *Christianity* (1995) Hans Küng used the concept of macro-, meso-, and microparadigms to structure the history of Christian theology around five major paradigms—Jewish Apocalyptic, Ecumenical Hellenistic, Mediaeval Roman Catholic, Protestant Evangelical, and Modern. Nancey Murphy used the Lakatosian concept in *Theology in the Age of Scientific Reasoning* (1990) in her contribution to the dialogue between science and religion.

In numerous areas of academic and nonacademic research, *paradigm* is used in a variety of ways. It is frequently spoken of in terms of new, emerging, or shifting paradigms. In the wake of a more pluralistic approach, an increasingly metaphorical use of the concept can be noted. The word *paradigm* has come to describe more or less well-defined bodies of knowledge or beliefs, world views, and guiding or dominant standards that are apt to change over time and that need not always be explicit. Nuances of *paradigm* are often value-laden: Paradigms are described both as enhancing creativity and as restricting creative thought and action.

See also WORLDVIEW

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PARADOX

Paradox appears in any context of explanation where two fundamental but contradictory (or contrary) propositions, both well-attested to be true, must be claimed simultaneously to provide a full and adequate account of the phenomenon in question. The nature of light as fully wave and fully particle according to the Copenhagen epistemology of complementarity, or the nature of the person of Jesus Christ as fully God and fully human according to Nicene theology, are both examples of irreducible paradox designed to explain the nature of a given phenomenon.

See also CHRISTOLOGY; COPENHAGEN INTERPRETATION; SELF-REFERENCE; WAVE-PARTICLE DUALITY

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PARALLEL DISTRIBUTED PROCESSING

See ARTIFICIAL INTELLIGENCE; INFORMATION TECHNOLOGY

PARTICLE PHYSICS

See PHYSICS, PARTICLE

PHASE SPACE

In classical mechanics, the complete state of a particle is given by three components of momentum and three components of position. The *phase space* of a particle is a six-dimensional space, three axes for momentum and three for position, so that each point of a particle's phase space represents a complete state of the particle, and the entire phase space represents all possible states of the particle. For an *N*-particle system, the phase space has 6*N* dimensions, 6 for each particle, and a single point in the phase space represents the simultaneous complete states for each of the *N* particles.

See also PHYSICS, QUANTUM

W. MICHAEL DICKSON

PHILOSOPHY OF RELIGION

Philosophy of religion can be broadly described as an inquiry into problems involved in religion or originated by religion from a philosophical point of view. Since, however, there are various understandings of religion and of philosophy and of the relation between them the field of philosophy of religion has become vast and varying. As a separate subject it originates from the European enlightenment, but its content can be traced back to the early stages of European philosophy, and there are rich traditions related to Hinduism, Buddhism, and Chinese religions. Islamic philosophers have also played an important role in the development of the subject. The focus of this entry lies on the Western philosophical tradition and its interplay with the Jewish and Christian religions.

The competence of reason. There is a widespread view according to which human reason lacks all ability to form any adequate idea of God. In the twentieth century the incompetence of reason in religious questions was clearly stated by the Swiss Protestant theologian Karl Barth (1886–1968) and his followers. The existence and actions of God can only be adequately dealt with in answer to the revealed word of God. Accordingly, religion and science belong to quite different sections of human activity, and ordinary philosophy is of minor importance compared to true religion. The bankruptcy of reason can hardly be defended by reasonable arguments, but it has an anchorage in feelings and experiences from various periods of the Christian tradition. The dominant view in Christian and Jewish traditions is that human reason is important for clarification of religious questions and that philosophy of religion provides a meeting ground for religion and science. A string of mysticism, however, often accompanies the religious thinking among those who defend the competence of human reason in the realm of religion.

Analysis of religious language. The use of symbols, metaphors, and analogies in religious language has attracted much philosophical interest, Thomas Aquinas's (c. 1225–1274) doctrine of analogy being an example. Analysis of language has been a main theme in modern philosophy of religion. Similarities to, and differences from, scientific language have been discussed. An analytic philosopher like Alfred J. Ayer denied the theoretical meaningfulness of religious language, but this was defended by John Hick, for example. A noncognitive view was developed by Richard B. Braithwaite, seeing God-talk as a commitment to an agapeistic form of life. Similar theories, as represented by D. Z. Phillips, have been developed on the basis of Ludwig Wittgenstein's later philosophy.

God in philosophical systems. The idea of God provides a cornerstone in the philosophical construction of the world by Plato and Aristotle. The influence from Plato and Aristotle in Western religious traditions can hardly be underestimated. Aristotle especially has often been a common point of reference both for scientists and theologians. Muslim philosophers, such as Averroës (1126–1198), brought the Aristotelian heritage to Christian scholasticism. Many arguments frequently used in later philosophy and relevant to the religion-science discussion are presented in the dialogue *De Natura Deorum* of Cicero (106–43 B.C.E.). In the further development of European philosophy, different concepts of God have played a decisive role, and the western philosophical tradition is hardly understandable without noticing the influence of Jewish and Christian theology. To the classical heritage from philosophy of religion belong Aquinas's philosophical arguments for the existence of God, the so-called Five Ways, the most influential being the cosmological and the teleological arguments.

René Descartes (1596–1650), who had great influence on the rise of modern science, offered many arguments for the existence of God, including the ontological one. An interesting pantheistic concept of God is important in Baruch Spinoza's (1632–1677) philosophy. He equates God and nature. A philosophical discussion that is especially fruitful for elucidating the relationship between religion and science followed the rise of so-called physico-theology and deism in the seventeenth and eighteenth centuries, its peak being Bishop George Berkeley's *Alciphron* (1732), Bishop Butler's *Analogy* (1736), and David Hume's *Dialogues Concerning Natural Religion* (1779). An idea of God separated from the theoretical and scientific realm is found in the philosophy of Immanuel Kant (1724–1804). God is a practical postulate, necessary for the development of morals. In twentieth-century philosophy, God as a principle involved in the development of nature can be encountered in Alfred North Whitehead's (1861–1947) complicated system.

Some modern philosophers of religion, including Frederick Copleston, Bernard Lonergan, and Richard Swinburne, argue that the traditional arguments for the existence of God can give a higher probability to the God hypothesis. Other modern philosophers, following Søren Kierkegaard (1813–1855), see the parallel between belief in God and a scientific hypothesis as completely misleading. According to Gordon Kaufman, the religious belief in God proceeds from an encounter with the holy, or, as William Alston argues, it can be founded on direct god-experiences. Inspired by the later Wittgenstein many philosophers have argued against all attempts to see doctrines of God as analogous to scientific theories.

Philosophical criticism of religion. The tradition of philosophical criticism of religion is often related to scientific development. It has been argued by Karl Marx (1818–1883), Sigmund Freud (1856–1939), and Emile Durkheim (1858–1917), among others, that the world can be understood without religious suppositions and the existence of religious ideas is explained by scientific arguments that contain no religious suppositions. A considerable part of the critical philosophy of religion, as represented by Hume, Kant, and Bertrand Russell (1872–1970), consists of criticism of the positive arguments indicated above. There are also classical debates focusing on contradictions in religious systems of doctrines; the best known is the relation between belief in a good God and the apparent evils of the world, as discussed by Gottfried Wilhelm Leibniz (1646–1716) and Voltaire (1694–1778). Since the 1970s, the religious consequences of the new evolutionary biology have been seriously debated, with some, like biologist Richard Dawkins, stating their atheistic implications, while others, including theologian Keith Ward, argue their compatibility.

Philosophical tools in religious thinking. The development of religious doctrines from the church fathers and onward is highly dependent on philosophical concepts. The tools from different branches of analytical philosophy have been used by Basil Mitchell and Antony Flew to clarify religious reasoning in the twentieth century. The same holds true for existentialism and other branches of contemporary philosophy, including postmodernism.

Many key questions in debates about the relation between religion and science emerge from the various fields of philosophy of religion presented above. Is it reasonable, for example, to seek a coherent model of the world, or is it impossible to advance further than developing good linguistic tools for different activities in life, such as prayer or physics? Can one base a worldview solely on scientific reasoning, and does it then contain or exclude the idea of a creator? Are there points of access to the real world other than purely empirical observation—religious and moral experiences for example? What happens when coherence is used as a criterion of truth in the totality of scientific, religious, moral, and aesthetic ideas?

See also ARISTOTLE; AVERROËS; COSMOLOGICAL ARGUMENT; DESCARTES, RENÉ; LANGUAGE; ONTOLOGICAL ARGUMENT; PANTHEISM; PLATO; TELEOLOGICAL ARGUMENT; THEODICY; THOMAS AQUINAS

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PHILOSOPHY OF SCIENCE

The phrase "philosophy of science" can be used most broadly to describe two different, though related, sorts of inquiry. On the one hand it can be used to describe the philosophy of particular sciences, such as the philosophy of physics, biology, or economics. On the other hand, it can be used to describe the study of epistemological issues in science more generally. Although an increasing majority of work in the philosophy of science is being done in the philosophy of particular sciences, it is this latter construal of the philosophy of science that remains the heart of the field and is the focus of this entry.

Scientific methodology

In a tradition that can be traced back to John Stuart Mill (1806–1873) and Francis Bacon (1561–1626), many have taken the scientific method to be inductive. An inductive inference is *ampliative* (i.e., the content of the conclusion goes beyond the content of the premises) and *nondemonstrative* (i.e., all true premises do not guarantee a true conclusion; at best they render the conclusion more probable). For example, suppose that one has observed a large number of mammals and every kind of mammal that one has observed has teeth; from this evidence one might make the inductive generalization that all mammals have teeth. It is possible, however, that the next mammal one observes (say, an anteater) might turn out not to have teeth. The fallibility of inductive inferences is often referred to as Hume's problem of induction, after the philosopher David Hume (1711–1776).

Carl Hempel (1905–1997) argues that the scientific method begins not with observations but with hypotheses. According to this hypothetico-deductive method one deduces certain observational predictions from the hypothesis and then rigorously tests them through further observation and experimentation. If the predictions are borne out, then the hypothesis is confirmed. Thus Hempel's method is still broadly inductive. Although the conclusion of an inductive argument is not certain, one would like to determine quantitatively how probable the conclusion is, given its premises (the evidence). The logical positivist Rudolf Carnap (1891–1970) sought to develop such a logic of confirmation. Other models of confirmation, such as Bayesian and bootstrapping models, are reviewed in John Earman's *Testing Scientific Theories* (1983).

Karl Popper (1902–1994) insists that the scientific method is deductive, not inductive. Observation always requires a prior point of view or problem. Like Hempel, Popper believes science begins with a bold hypothesis or conjecture. The way in which the scientist comes to the hypothesis (context of discovery) is irrelevant (e.g., it could come to the scientist in a dream); all that matters is the way in which it is tested (context of justification). Unlike Hempel, Popper does not think that hypotheses can be confirmed. If the observational prediction is borne out, deductively the scientist is unable to conclude anything (to conclude that the hypothesis is confirmed is to commit the deductive fallacy of affirming the consequent). If, however, the predictions are falsified, then, by the valid deductive inference *modus tollens* (if *p* then *q,* not *q,* therefore not *p*) one can conclude that the hypothesis is falsified. Hence, Popper's method is known as *falsificationism.* According to Popper, the scientist should not seek to confirm theories but rather, refute them. A theory that has survived repeated attempts of falsification—especially in those cases where it has made risky predictions—has been corroborated, though not confirmed. On this view, a theory is demarcated as scientific if there are observational conditions under which one would be willing to reject the theory as falsified.

As a matter of historical fact, however, scientists typically do not abandon their theories in the face of falsifying evidence. Furthermore, in many cases it turns out to be sound scientific judgment to continue developing and modifying a theory in the face of recalcitrant evidence. In response to these sorts of difficulties, Popper's student, Imre Lakatos (1922–1974), developed a sophisticated falsificationism known as the "methodology of scientific research programs." For Lakatos, instead of evaluating an individual theory or modification of a theory as scientific or ad hoc, one should evaluate a whole series of theories developed over time. This series, called a *research program,* consists of a *hard core,* which defines the research program and is taken to be irrefutable, and a *protective belt,* which consists of auxiliary hypotheses and background assumptions to be modified in the face of falsifying data, thereby protecting the hard core. According to Lakatos, a research program is demarcated as scientific if it is progressive—that is, it continues to make new predictions that become corroborated. Once a research program ceases to make new corroborated predictions it becomes degenerative and its hard core should be abandoned.

Paul Feyerabend (1924–1994) was a close friend of Lakatos and also a student of Popper's. In his book *Against Method* (1978) he denies that there is such thing as the scientific method. He writes, "the idea of a fixed method, or a fixed theory of rationality, rests on too naïve a view . . . there is only *one* principle that can be defended under *all* circumstances. . . . It is the principle: *anything goes*" (pp. 27–28). Feyerabend's view is known as *epistemological anarchism.*

Scientific rationality and theory change

Beginning in the early 1960s there was a shift away from concerns about scientific methodology towards concerns about scientific change. This shift was in large part due to the publication in 1962 of Thomas Kuhn's (1922–1996) *The Structure of Scientific Revolutions.* Kuhn argues that the philosophy of science ought to be the product of a careful examination of the history of science. This involves recognizing the integrity of the science within its own time and not simply viewing it in relation to one's contemporary perspective. This new historiographical approach leads Kuhn to reject much of traditional philosophy of science: the confirmationist and falsificationist accounts of theory evaluation, the view that science is cumulative, the distinction between context of discovery and context of justification, and the idea of a crucial experiment.

Kuhn argues that science is characterized by three sorts of phases: pre-paradigm science, normal science, and revolutionary science. Central to understanding these phases is his notion of a *paradigm,* which he uses in two primary ways. First, he means an exemplar, a concrete problem solution or scientific achievement that serves as a model for solving other scientific problems (e.g., the planetary dynamics laid out in Isaac Newton's *Principia*). Second, and more broadly, he means by paradigm a disciplinary matrix, which includes not only exemplars, but laws, definitions, metaphysical assumptions, and values (e.g., Newton's dynamical laws, the definitions of mass and space, and the mechanical philosophy). The paradigm determines what is to count as an acceptable scientific problem and an acceptable scientific solution. In the process of normal science, anomalies emerge that resist solution within the framework of the paradigm; if these anomalies persist and proliferate, they can lead to a state of crisis. Revolutionary science is described as "those noncumulative developmental episodes in which an older paradigm is replaced in whole or part by an incompatible new one" (p. 92). Kuhn refers to the pre- and post-revolutionary periods of normal science as incommensurable, and says that there is a sense in which scientists from different paradigms work in different worlds. Kuhn polemically refers to the conversion from the old to the new paradigm as being analogous to a Gestalt switch or religious conversion. Ian Barbour draws analogies between Kuhnian paradigms and religious paradigms in *Religion and Science* (1997).

In the 1969 postscript to *The Structure of Scientific Revolutions* and in the article "Objectivity, Value Judgment, and Theory Choice" (1977) Kuhn responds to charges that his account of science makes science irrational and leads to relativism. Against the charge of irrationality, Kuhn notes that values (such as predictive accuracy, simplicity, internal consistency, and coherence with neighboring theories) provide scientists with a shared basis for theory choice. Against the charge of relativism, Kuhn notes that ultimately paradigms are to be evaluated by their ability to set up and solve "puzzles." In this sense Kuhn does believe that there is objective progress in science: Newton solves more puzzles than Aristotle, and Albert Einstein more puzzles than Newton. What Kuhn rejects is realism, which claims that there is a coherent direction of ontological development and that science is getting closer to the truth.

Subsequent philosophers of science influenced by Kuhn developed different strands of his thought in different directions. Feyerabend, who developed an incommensurability thesis around the same time as Kuhn, came to later embrace the label of relativist. Others, such as Larry Laudan, sought to preserve the rationality of science against the threat perceived in Kuhn's holist picture of scientific change. According to Laudan, a closer look at the history of science shows not a wholesale exchange of one paradigm for another, but rather the components of the disciplinary matrix (e.g., methods, values, and ontology) being negotiated individually. Regarding theory choice he writes, "there is enough common ground between the rivals to engender hope of finding an 'Archimedean standpoint' which can rationally mediate the choice" (1984, p. 75). He calls this alternative view the reticulated model of scientific change.

Scientific realism versus antirealism

The labels *realism* and *antirealism* are each used to cover a wide spectrum of views. The main positions can be roughly distinguished by their answers to three questions: (1) Is there a mind-independent world? (2) What is our epistemic access to that world? (3) What is the aim of science? Realists (along with many antirealists) accept the existence of a mind-independent world. Those antirealists who deny this advocate some form of idealism. While realists tend to be optimistic about epistemic access to the world, antirealists argue in various ways that this optimism is unwarranted. Realists typically see the aim of science being truth, whereas antirealists argue the aim is something less.

At one end of the realist spectrum is naïve realism—the view that science is a perfect, undistorted mirror of the mind-independent world and that scientific theories are literally true. More sophisticated versions of realism, such as the view of Ernan McMullin, hold that realism means the long-term success of a scientific theory gives reason to believe that something like the entities and structures postulated by the theory actually exist (p. 26). According to McMullin, an important part of the aim of science is the development of fruitful metaphors. Many have argued for realism on the grounds that it provides the best explanation for the success of science; the widespread success of science would be "miracle" if scientific theories were not at least approximately true (Boyd 1984, Putnam 1975). Others argue that the proper question for realism is not whether some theory is true or approximately true, but whether some entity exists. According to Ian Hacking's entity realism, one can conclude, for example, that electrons exist because researchers experimentally build devices that use electrons to investigate other parts of nature. Between theory realism and entity realism is another view known as *structural realism*. This view, which John Worrall attributes to Henri Poincaré

(1854–1912), affirms a mind-independent world but takes epistemic access to that world to be limited to its structural features. Thus, there is a continuity of structure across theory change despite radical changes in ontology. Although what is meant by *structure* is not entirely clear, in the physical sciences it is typically taken to be the structures expressed in the mathematical formalism of the theory.

Challenges to realism come from many sources and have led to a variety of antirealist views. Both Kuhn (1962) and Laudan (1981) argue that the history of science undermines realism. Kuhn's view can be classified as a form of instrumentalism, according to which scientific theories are merely useful instruments for making predictions and solving problems. Other antirealist views, such as Bas van Fraassen's constructive empiricism, come out of the empiricist tradition. According to van Fraassen (1980), science only aims to give theories that are empirically adequate and a theory is empirically adequate if what it says about observable things is true, that is, if it saves the phenomena (p. 12). On this view, one is not compelled to accept the existence of unobservable entities, such as electrons.

A third strand of antirealism, known as *social constructivism,* comes from sociology. The social constructivist seeks to understand scientific practice in the laboratory in a manner similar to an anthropologist seeking to understand a foreign culture. Social constructivists, such as David Bloor of the Edinburgh School, reject the philosophical understanding of knowledge as justified true belief, and instead take knowledge to be whatever is collectively endorsed by a particular group of people at a particular time (p. 5). This makes social constructivism a form of relativism. It is called *constructivism* because it takes scientific knowledge and facts to be constructed rather than discovered. Stronger and weaker versions of this view are obtained depending on whether this process of constructing scientific knowledge is, or is not, taken to be purely social. Arthur Fine, who argues that social constructivism has important methodological lessons for the philosophy of science (1996), himself rejects both realism and antirealism. Instead Fine advocates a minimalist position he calls the *natural ontological attitude,* which prescribes accepting the claims of science in the same way that one accepts the evidence from one's senses, without adding any additional claims such as "and it is really true" or "and it is only a useful fiction" (1986, p. 127).

Feminist philosophies of science

Since the 1970s, many feminist philosophers, historians, and scientists have been asking why there have traditionally been so few women in science and whether certain sexist, racist, or nationalist biases have shaped the practice and content of science. Detailed case studies, a representative sample of which can be found in Janet Kourany's *The Gender of Science* (2001), reveal many ways in which such biases have affected science. In response to these findings, many feminists sought to develop a new epistemology or philosophy of science. Following Sandra Harding (1986), feminist philosophies of science can be roughly divided into three traditions: feminist empiricism, feminist standpoint theory, and feminist postmodernism.

Helen Longino, whose work falls largely within the feminist empiricist tradition, introduces a view known as *contextual empiricism.* Longino sees empirical data as constraining, but nonetheless underdetermining, theory choice. This gap between theory and evidence is bridged by value-laden background assumptions belonging to a particular context. These contextual assumptions are one way biases can enter science. Longino criticizes traditional portrayals of the scientific method as individualistic. Instead she sees the objectivity of science being secured by its social character (e.g., peer review, replication of experiments, and an openness and responsiveness to criticism). She argues that diversity in science is important for making these often invisible assumptions explicit and open to criticism.

Harding takes this point about diversity in science a step further in her feminist *standpoint theory.* In contrast to empiricism, standpoint theory argues that the legitimacy of the knowledge claim depends on the social identity of the knower. Harding writes, "women's subjugated position provides the possibility of more complete and less perverse understandings. Feminism . . . can transform the perspective of women into a 'standpoint'—a morally and scientifically preferable grounding for our interpretations and explanations of nature" (p. 26). One standard criticism that Harding considers is whether there is such a thing as a "feminist standpoint" that cuts across all classes, races, and cultures.

Donna Haraway's work *Simians, Cyborgs, and Women* (1991) exemplifies the feminist postmodernism tradition. Haraway rejects the idea of single feminist standpoint and instead argues that all knowledge is locally situated. Like Longino, Haraway offers an alternative account of objectivity. She writes, "Feminist objectivity is about limited location and situated knowledge, not about transcendence and splitting of subject and object. In this way we might become answerable for what we learn how to see" (p. 190). Although Haraway's view shares some affinities with social constructivism, she explicitly rejects the label "relativist." She explains, "the alternative to relativism is not totalization and single vision. . . . [Rather, it is] partial, locatable, critical knowledges. . . . Relativism is a way of being nowhere while claiming to be everywhere equally. The 'equality' of positioning is a denial of responsibility and critical enquiry" (p. 191). Underlying many of these feminist philosophies is a central concern for the social and ethical implications of science.

Scientific explanations and laws

The most influential account of scientific explanation is Hempel's *covering law model.* On this model, explanations are understood as arguments in which the explanandum (the event, feature, or law to be explained) appears as the conclusion of an argument. The premises of the argument must contain at least one universal or statistical law used essentially in the derivation, and empirically verifiable statements describing particular facts or initial conditions. If the argument is deductive and involves a universal law, it is called a *deductive-nomological explanation*; if the argument is inductive and involves a statistical law, then it is called an *inductive-statistical explanation.* For example, suppose one wants to understand why an ice skater's angular velocity increases as she draws her arms in during a spin. The explanation would show that this event can be logically deduced from premises involving the law of conservation of angular momentum and statements such as her initial angular momentum was nonzero and her moment of inertia was reduced by drawing her arms in.

Several philosophers and historians have objected that Hempel's conditions are neither necessary nor sufficient for a scientific explanation. The most famous counterexamples fall into the categories of either irrelevance (although the event follows from the premises, as a matter of fact those premises are irrelevant to the explanation of the event) or symmetry (if the law involves a biconditional or equation then one can switch one of the premises with the conclusion and "explain" things such as why a flagpole is a certain height in terms of the length of its shadow). These sorts of problems have led philosophers largely to abandon Hempel's model and propose new alternatives. To handle the problems of irrelevance and symmetry, Wesley Salmon (1925–2001) introduces a causal model explanation, whereby to explain an event is to identify the causes of that event. Alternatively, van Fraassen in his pragmatic account of explanation embraces the possibility that the length of a shadow may explain the height of a pole. For van Fraassen (1980), an explanation is always relative to a particular context. Yet another model of explanation is provided by Philip Kitcher (1981), who understands explanation to be a unification of diverse phenomena by means of a common underlying structure or small number of processes. He sees Charles Darwin's theory of evolution as illustrating this model of explanation. The link between explanation and unification is challenged by Margaret Morrison in her book *Unifying Scientific Theories* (2000).

From reductionism to theoretical pluralism

Reductionism can be construed as a thesis about ontologies, laws, theories, linguistic expressions, or some combination of these. Considered as a relationship between scientific theories, it can be taken as a synchronic relation between two concurrent theories belonging to different levels of description or a diachronic relation between a historical predecessor theory and its successor. The classic formulation of theory reduction is due to the logical empiricist Ernest Nagel (1901–1985), who takes it to involve the logical derivation of one theory from another. More specifically, "a reduction is effected when the experimental laws of the secondary science . . . are shown to be the logical consequences of the theoretical assumptions . . . of the primary science" (p. 352). The standard example is the reduction of thermodynamics (secondary science) to statistical mechanics (primary science). In the physical sciences, reductionism is more often taken to be a correspondence between two theories under certain conditions, typically characterized by the limit of some quantity. As Thomas Nickles notes, this view is "best described by 'inverting' the usual concept of reduction, so that successors are said to reduce to their predecessors . . . under limiting operations" (p. 181). For example, special relativity is said to reduce to Newtonian mechanics in the limit of small velocities.

Challenges to reductionism have come from detailed case studies of the relations between particular scientific theories. One recurring challenge is known as the problem of *multiple realizability*. For example, in reducing Mendelian genetics to molecular biology, as Alexander Rosenberg points out in his 1989 "From Reductionism to Instrumentalism?",one discovers that a single Mendelian trait can be realized by a variety of molecular mechanisms, and furthermore, the same molecular mechanism can produce different Mendelian characteristics. Another set of challenges arises when the reducing theory is statistical (such as statistical mechanics or quantum mechanics) and the reduced theory is not as Lawrence Sklar indicates in this 1999 essay, "The Reduction (?) of Thermal Dynamics to Statistical Mechanics." These sorts of difficulties have led many to reject reductionism and instead argue for theoretical pluralism, or the so-called disunity of science. According to pluralism, each scientific theory has its own proper domain of applicability. In her book, *The Dappled World* (1999), Nancy Cartwright raises the possibility that "nature is governed in different domains by different systems of laws not necessarily related to each other in any systematic or uniform way" (p. 31). This view has been criticized on the grounds that it forfeits the benefits that come from examining inter-theoretic relations. The question of the unity or disunity of science remains a controversial topic.

See also EXPLANATION; PHILOSOPHY OF SCIENCE, HISTORY OF; POSITIVISM, LOGICAL

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PHILOSOPHY OF SCIENCE, HISTORY OF

In tracing the history of the philosophy of science, it should be noted that philosophy and science were not clearly distinguished from each other until the early eighteenth century; furthermore, the philosophy of science, as a distinct subdiscipline, did not emerge until the nineteenth century. Nonetheless, almost from the beginning of philosophy, there were thinkers who reflected on the methods, aims, and epistemological status of inquiry into nature. In this respect, Aristotle (384–322 B.C.E.) is generally regarded as the first philosopher of science.

Ancient and medieval periods

Aristotle's views on the philosophy of science are primarily found in his *Posterior Analytics.* For Aristotle, genuine scientific knowledge has the status of necessary truth. This necessity comes from the fact that scientific explanations are to be demonstrations—that is, logical deductions from premises that are necessarily true. He argued that these premises must function as "first principles," which are primitive (they cannot themselves be demonstrated), known immediately, and known better than the conclusions. Each science, whether it be zoology or physics, has its own first principles. Aristotle thought that we come to know these first principles inductively through experience; that is, we can intuit or perceive the essences of things in our observations of nature.

In the Middle Ages, reflections on the scientific method were primarily focused on elaborations and criticisms of the views laid out in Aristotle's *Posterior Analytics* (which was reintroduced to Western scholars in the twelfth century). In the thirteenth and fourteenth centuries many scholars began to call into question Aristotle's assertion that scientific knowledge is demonstrative—that it, has the status of necessary truth. For many theologians, this assertion seemed to be in conflict with the doctrine of God's omnipotence and with revelation as the preeminent source of knowledge. The growing tension between Aristotelian natural philosophy and church doctrine led the Bishop of Paris, Etienne Tempier, in 1277 to issue a condemnation of 219 propositions. Among these were propositions relating to Aristotle's views that the world is eternal and that a vacuum is impossible. Both Pierre Duhem and the contemporary historian of science Edward Grant has argued that the condemnation of 1277 was an important stone in paving the way, not only for the scientific revolution, but for new philosophical views about the methods and epistemological status of science.

Early modern period

In 1620 Francis Bacon (1561–1626) published his *Novum Organum,* or *New Organon,* in which he laid out a new philosophy and methodology of science that he hoped would replace Aristotle's *Organon* (the name given to the collection of Aristotle's six books on logic and scientific method: *Categories, De Interpretatione, Prior Analytics, Posterior Analytics, Topics,* and *Sophistical Refutations*). Whereas Aristotle emphasizes deductions from necessary first principles, Bacon emphasizes induction as the central scientific method. Bacon was not, however, a naïve inductivist: He notes that impressions from the senses can be deceptive and that it is a bad induction to infer the principles of science through simple enumeration (*Novum Organum,* Book I, Aphorism 69). Bacon famously compares the proper scientist to a bee:

> Those who have handled the sciences have been either Empiricists or Rationalists. Empiricists, like ants, merely collect things and use them. The Rationalists, like spiders, spin webs out of themselves. The middle way is that of the bee, which gathers its materials from the flowers . . . but then transforms and digests it by a power of its own. (*Novum Organum,* Book I, Aphorism 95)

Bacon is often referred to as the father of experimental science. Instead of simply observing nature, Bacon advocates the use of experiments, which are skillfully thought out and framed for the purpose of inquiry. An important and controversial legacy of Bacon's philosophy of science is his notion of a crucial experiment or "instance of the fingerpost" (described in Aphorism 36 of Book II), which is designed to unambiguously decide in favor of one hypothesis or theory and refute another.

Although René Descartes (1596–1650), like Bacon, saw himself as providing a new epistemological foundation for science, in many respects his views on science were a return to the Aristotelian ideal of science as a set of deductions from necessary first principles. According to Descartes, these first principles are known not through observations, but by the "light of nature" that is given to us by God. Towards the end of his life, however, Descartes seemed to concede that this deductive ideal is unattainable.

Descartes's contemporary, Galileo Galilei (1564–1642), blended a Baconian emphasis on experimentation with a Cartesian emphasis on the importance of geometry for physics. In *The Assayer* he famously claims:

> Philosophy is written in this grand book, the universe, which stands continually open to our gaze. But the book cannot be understood unless one first learns to comprehend the language and read the letters in which it is composed. It is written in the language of mathematics, and its characters are triangles, circles, and other geometrical figures. (p. 238)

One of Galileo's most important contributions to the methodology of science is his use of idealization. As Ernan McMullin (1985) notes, Galileo uses not only mathematical idealization, but also a sort of causal idealization, whereby one considers nature not in its full causal complexity but in an idealized situation in which all but the causal line of interest have been eliminated. Whether the conclusions drawn from these "artificial" scenarios apply to nature in its full complexity as well was an issue of debate between Galileo and the Aristotelian natural philosophers.

Scientific Revolution

In the generation following Descartes, Christian Huygens (1629–1695) argues that the method of science differs distinctly from that of geometry and that the conclusions of science are, at best, highly probable. In the preface to his *Treatise on Light,* he argues for the hypothetico-deductive method in science. According to this method one first puts forward a hypothesis and then deduces from it certain observational predictions. If those predictions are born out then the hypothesis is rendered more probable.

Isaac Newton (1642–1727), by contrast, famously declared that hypotheses have no proper place in science—a declaration that was not entirely consistent with his practice. In the General Scholium to his *Principia* he writes, "I frame no hypotheses; . . . and hypotheses, whether metaphysical or physical, whether of occult qualities or mechanical, have no place in experimental philosophy" (p. 443). Instead, Newton advocates the method of analysis and synthesis, which he describes in Query 31 at the end of his *Opticks.* According to this method one begins with "analysis," which consists of making observations and experiments and then inductively drawing conclusions from them. Once one has these inductive generalizations in hand, the method of "synthesis" consists in using them in turn to explain the phenomena. Although Newton's name is often associated with the godless mechanistic worldview, Newton himself believed that blind necessity could not account for the diversity in the world (General Scholium). He furthermore believed that the uniform motions of the planets required the intervening maintenance of God. In Query 31 of the *Opticks* he writes:

> For it became him who created them [all material things] to set them in order. And if he did so, it is unphilosophical to seek for any other Origin of the World, or to pretend that it might arise out of Chaos by the mere Laws of nature. . . . [B]lind Fate could never make all the Planets move one and the same way in Orbs concentrick [sic]. (p. 402)

By the end of the eighteenth century an important shift had taken place, namely figures such as Huygens and Newton realized that the empirical sciences could at best yield probable knowledge; the ideal of scientific knowledge as certain knowledge came to be largely abandoned.

Early nineteenth century

In the early nineteenth century three important books were published on the philosophy of science: John Herschel's *A Preliminary Discourse on the Study of Natural Philosophy* (1830), William Whewell's *The Philosophy of the Inductive Sciences, Founded Upon Their History* (1840), and John Stuart Mill's *System of Logic* (1841). In Part I of his *Discourse* Herschel defends the study of natural philosophy (science) against the charge that it leads one to "doubt the immortality of the soul, and to scoff at revealed religion," arguing instead that it leads to the betterment of one's moral character and undermines atheism (section 5). In Part II of the *Discourse* he lays out three methods by which one can come to discover scientific laws: first, by inductive reasoning; second, "by forming at once a bold hypothesis . . . and trying the truth of it by following out its consequences and comparing them with facts" (section 210); and third, by a process that combines both. With regard to the second (hypothetico-deductive) method, Herschel notes "when a theory will bear the test of such extensive comparison, it matters little how it has been original framed" (section 220). Passages such as this have led the contemporary philosopher of science John Losee to attribute to Herschel the invention of the distinction between what Hans Reichenbach (1891–1953) would later call the "context of discovery" and the "context of justification."

Whewell (1794–1866) was the first philosopher of science to take the historical turn, arguing that the philosophy of science ought to reflect—and be a product of—a close historical examination of the practice of science. Despite this important insight, Whewell's own philosophy of science was probably to a greater extent shaped by the philosophies of Bacon and Immanuel Kant (1724–1804), than the history of science. Like Herschel, Whewell recognizes the important role that hypotheses play in science, though he thinks that these hypotheses are to be grounded inductively. Whewell sees his work as a renovation of the inductive method laid out in Bacon's *Novum Organum.* The most striking renovation was Whewell's (Kantian) claim that the mind supplies from within itself certain "fundamental ideas" that shape, and are a necessary precondition for, experience and the empirical knowledge on which the sciences are based. Whewell represents a surprising return to the claim that science aims for, and can obtain, the status of necessary truth. The contemporary philosopher of science, Laura Snyder, has cogently argued that these two aspects of Whewell's philosophy of science (fundamental ideas and empirical science as necessary truths) can be properly understood only in the context of his natural theology. Snyder explains:

> we are able to have knowledge of the world because the Fundamental Ideas which are used to organize our sciences resemble the Ideas used by God in his

> creation of the physical world. . . . [T]he Divine origin of both our Ideas and our world is what enables Whewell to claim that axioms knowable a priori from the meanings of our Ideas are informative about the empirical world, and necessarily true of it. (p. 796)

In 1833 Whewell contributed his "Astronomy and General Physics Considered with Reference to Natural Theology" to the well-known Bridgewater Treatises.

John Stuart Mill (1806–1873) debated Whewell on the nature of induction in science. In Book II, chapter 5 of his *System of Logic* Mill rejects Whewell's claim that science can obtain the status of necessary truths. Mill writes:

> I may have seen snow a hundred times and may have seen that it was white, but this cannot give me entire assurance even that all snow is white, much less that snow *must* be white. However many instances we may have observed of the truth of a proposition, there is nothing to assure us that the next case shall not be an exception to the rule . . . experience cannot offer the smallest ground for the necessity of a proposition. (pp. 155–156)

Here it is clear that Mill is squarely in the empiricist tradition of David Hume (1711–1776) and is construing induction narrowly as induction by simple enumeration. Mill's best known contribution to the philosophy of science is his four methods of experimental inquiry (typically referred to as "Mill's Methods" though, as Losee and others have noted, they can be found in the works of earlier medieval natural philosophers) described in chapter 8 of Book III of *System of Logic*. They can be summarized as follows:

- Method of Agreement: If two or more instances of the phenomenon have only one circumstance in common, the circumstance in which the instances agree is the cause of the phenomenon.
- Method of Difference: If an instance when the phenomenon under investigation occurs and an instance in which it does not occur have every circumstance in common save one, then that circumstance by which they differ is the cause (or an indispensable part of the cause) of the phenomenon.
- Method of Residues: Subtract from any phenomenon those parts that are known to be the effect of certain antecedent causes; the remaining part of the phenomenon (the residue) is the result of the remaining antecedents.
- Method of Concomitant Variations: Whatever phenomenon varies when another phenomenon varies is either a cause, or an effect of that phenomenon or is causally related to it some way (e.g., both the product of a common cause).

Late nineteenth and early twentieth centuries

New challenges to the English inductivist tradition came from the French physicist and historian of science Pierre Duhem (1861–1916). Duhem argues that physics is subject to certain methodological limitations that do not affect other sciences. In his book *The Aim and Structure of Physical Theory* (1914) Duhem provides a devastating critique of Baconian crucial experiments. According to Duhem, an experiment in physics is not simply an observation, but rather, is an interpretation involving a theoretical framework. Furthermore, no matter how well one constructs one's experiment, it is never a single hypothesis that faces an experimental test. Instead, it is a whole interlocking group of hypotheses, background assumptions, and theories. This thesis has come to be known as *holism*. According to Duhem, it is this holism that renders crucial experiments impossible. More generally, Duhem is critical of Newton's description of the method of physics as a firm and straight forward "deduction" from facts and observations.

In the appendix to *The Aim and Structure,* entitled "Physics of a Believer," Duhem draws out the implications that he sees his philosophy of science as having for those who argue that there is a conflict between physics and religion. He writes, "metaphysical and religious doctrines are judgments touching on objective reality, whereas the principles of physical theory are propositions relative to certain mathematical signs stripped of all objective existence. Since they do not have any common term, these two sorts of judgments can neither contradict nor agree with each other" (p.

285). Nonetheless, Duhem argues that it is important for the theologian or "metaphysician" to have detailed knowledge of physical theory in order not to make illegitimate use of it in speculations.

This separation of physics from metaphysics that Duhem describes is characteristic of the positivist movement founded by Auguste Comte (1798–1857) and developed by the Austrian physicist and philosopher Ernst Mach (1838–1916). Mach's philosophy can be characterized as a form of sensationalism, according to which the world consists not of things, but sensations. In other words, an object, such as an apple, is nothing but a composite of various elements of sensations: red, round, crunchy, and sweet; and talk about apples is really just an economical way of talking about collections of sensations. Indeed, all scientific theories, for Mach, are just economical ways of talking about sensations. Mach's elements of sensation are neither subjective, nor purely mental: Sensations can also be considered physical in so far as they depend in various ways on each other. Although this view may be reminiscent of Bishop George Berkeley's (1685–1753) idealism (the view that there are no material substances—only ideas and the minds that contain them), Mach explicitly distinguishes his view from both Berkeley and Kant: "Berkeley regards the 'elements' [of sensation] as conditioned by an unknown cause external to them (God); accordingly Kant, in order to appear as a sober realist, invents the 'thing-in-itself'; whereas, on the view which I advocate, a dependence of the 'elements' on one another is theoretically and practically all that is required" (pp. 361–362). Mach sees sensationalism as providing a framework in which to unify the newly emerging psychological sciences with the physical sciences. Both progress and unification require eliminating all concepts in physics that do not correspond directly to sensations (i.e., eliminating all metaphysical concepts). On these grounds, Mach famously denied atomism, which he took to be an unnecessary metaphysical assumption. Mach's philosophy—in particular, his rejection of metaphysics and concern for the unity of science—greatly influenced the founders of the Vienna Circle.

Henri Poincaré (1854–1912) was a French physicist, mathematician, and philosopher. In the preface to his *Science and Hypothesis* (1902) he distinguishes three kinds of hypotheses in science: "some are verifiable, and when once confirmed by experiment become truths of great fertility; . . . others may be useful to us in fixing our ideas; and finally, . . . others are hypotheses only in appearance, and reduce to definitions or to conventions in disguise" (p. xxii). It is his defense of this third kind of "hypothesis" that makes Poincaré's philosophy of science a form of conventionalism. While he does not think that all of science is a matter of convention, he does take the geometry of space and certain principles of mechanics to be simply stipulated, rather than discovered. By saying that something is conventional, Poincaré does not mean that it is arbitrary—there are certain constraints and consequences that come with fixing a convention. For example, although neither logic nor experience forces us to accept Euclidean geometry, rather than non-Euclidean geometry, as the correct description of our space (i.e., it is a free choice), choosing to adopt one geometry rather than another will require us to adjust our physical theories in certain ways (e.g., will require introducing new forces). Despite his conventionalism, Poincaré adopts a realist stance toward science. He writes, "we daily see what science is doing for us. This could not be unless it taught us something about reality; the aim of science is not things themselves . . . but the relations between things" (p. xxiv). This has led some contemporary philosophers to attribute to Poincaré the first expression of a view known as structural realism. Poincaré concludes the preface to his book by noting, "No doubt at the outset theories seem unsound, and the history of science shows us how ephemeral they are; but they do not entirely perish, and of each of them some traces still remain. It is these traces which we must try to discover, because in them and in them alone is the true reality" (p. xxvi). While Poincaré's remarks may or may not be true of the history of science, they do seem to be true of the history of philosophy of science.

See also PHILOSOPHY OF SCIENCE; SCIENCE AND RELIGION, HISTORY OF FIELD

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PHYSICALISM, REDUCTIVE AND NONREDUCTIVE

Physicalism is a doctrine that asserts that ultimately only physical particulars exist. While physicalism and materialism are sometimes considered equivalent, the former is more ontologically open, for while materialism claims that everything is composed of matter, physicalism holds that everything is comprised ultimately of those entities assumed in the basic statements of fundamental physical theory (fields, particles, strings, or whatever). The thesis that only these physical entities exist is often termed *ontological physicalism.*

While ontological physicalism is often presupposed in the philosophical discussion, controversy arises about the properties possessed by these physical particulars. For example, what is the ontological status of putative mental properties? Are they reducible to underlying physical properties, or do they have a kind of being of their own? The reductive physicalist affirms, while the nonreductive physicalist denies, that mental properties are "nothing but" the physical. Broadly conceived, reductive physicalism asserts that all nonphysical properties are coextensive with particular physical properties. Nonreductive physicalism, on the other hand, conjoins the irreducibility of nonphysical properties (property dualism) to ontological physicalism.

Since the 1960s considerable doubt has been cast on the reductive physicalist project. In Ernest Nagel's (1901–1985) classic account, physicalist reduction occurs when nonphysical predicates are biconditionally connected to particular physical predicates such that the nonphysical property is instantiated when and only when a particular physical property is instantiated, (e.g., the mental property of a particular headache pain is instantiated when and only when a particular neuro-property is). However, one can imagine a silicon-based Martian having the same headache pain as an earthling, but because of the Martian's different neurophysiology, different physical properties will be instantiated. Because the same mental state seems to be realizable in different physical systems, reductive physicalism is called into question. Consequently, nonreductive physicalism has generally replaced reductive physicalism in the philosophy of mind. Accordingly, while the instantiation of an upper-level mental property is not reducible to the instantiation of a lower-level one, it is nonetheless realized by some lower-level property. Thus, instead of a *type* identity between property kinds, (every time mental property *m* is instantiated, physical property *p* is instantiated), there is a *token* identity between an instantiation of *m* and the instantiation of some physical property or other.

Issues of reductive and nonreductive physicalism are important in the science/theology discussion. If, as the natural sciences methodologically assume, only physical entities have causal powers and hence ultimately exist, then what kind of sense can be made of religion and its talk of God? In responding to this problem, nonreductive physicalism seems initially promising, for it holds with the natural sciences that only physical entities exist, and yet agrees with religion in claiming that there are irreducible nonphysical properties. If it can be shown that our mental life is irreducible to neuroscience, then insofar as religion concerns our mental life, it too is irreducible to the physical.

But large questions loom. Can upper-level properties be something more than mere epiphenomena, if they are token identical to physical properties that do all the causal work? Alternately, if physical properties do not do all the causal work, can dualism be avoided? Finally, if the irreducible mental is nonetheless completely realized by the physical, then in charting this physical realization, is one not offering a reductive explanation of the mental, and its religious experience, after all?

See also MATERIALISM; MIND-BRAIN INTERACTION; NATURALISM; REDUCTIONISM; SUPERVENIENCE

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PHYSICS

Physics is the branch of scientific investigation that focuses its attention on fundamental concepts, patterns, and relationships involving matter, energy, space, and time. Other natural sciences, such as chemistry, biology, geology, and astronomy, also deal with these categories in their investigation of material systems like atoms, molecules, life processes, organisms, planets, stars, and galaxies, but physics is concerned with the most basic and universal principles that apply to all of these diverse systems.

It is sometimes convenient to divide physics into several different arenas of concern, such as mechanics (the study of motion), electromagnetism and optics, thermodynamics, quantum physics, atomic physics, nuclear physics, particle physics, and relativity (the study of space, time, and gravity).

Classical mechanics is the study of motion in the manner established by Isaac Newton in the seventeenth century. Among its major contributions is a fruitful method for describing the cause-effect relationship for motion in a quantifiable manner. A force, like the familiar push or pull, functions as the cause of acceleration (any change in the speed or direction of motion), which is its effect. Another major contribution of Newton was his concept and description of the force of gravity that is experienced and exerted by every object possessing the quality of mass. The gravitational force that causes apples to fall earthward is also the kind of kind of force that steers the moon in its orbit around the Earth and the planets in their orbits around the sun.

Electromagnetism encompasses all phenomena in which electric and magnetic fields play a role. In classical physics, fields may be thought of as qualities of space that lead objects with certain properties to experience a force. Any object possessing the property of electric charge, for example, will experience a force in the presence of an electric field. Electromagnetic radiation (light, X-rays, radio waves) may be understood as variations in electric and magnetic fields that travel at the characteristic speed of three hundred thousand meters per second through space.

Thermodynamics is concerned with the manner in which energy, especially heat energy, affects the state of a system and its interaction with its environment. Energy, often characterized as the capacity to do work, appears in a diversity of forms and may be changed in either form or location as a consequence of some physical process. In all processes, however, the sum of the energy possessed by a system and its environment remains constant. This principle, called the First Law of Thermodynamics, or the conservation of energy, is thought to apply without exception to all physical phenomena.

Quantum theory describes the structure and behavior of systems like atoms, atomic nuclei, and molecules. Extremely small structures behave in a manner different from the predictions of classical mechanics. The quantities of energy possessed by a system or exchanged between systems, for instance, is restricted to certain values only. Furthermore, the outcome of many processes is open to diverse options, each outcome having a calculable probability of occurrence.

Relativity theory provides a framework for speaking of the interactive relationships among space, time, mass, and gravity. Special Relativity describes the way in which the experience of time and space are interrelated, while General Relativity focuses its attention on the interrelationships among mass, space, gravity, and motion.

See also COSMOLOGY, PHYSICAL ASPECTS

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PHYSICS, CLASSICAL

Classical physics is the science of physics as it was conceptualized and practiced in the three centuries prior to the advent of either quantum physics or relativity early in the twentieth century. The character of classical physics is well-represented by Isaac Newton's (1642–1727) formulation of the study of motion and James Clerk Maxwell's (1831–1879) approach to the study of electromagnetism.

Classical mechanics

Classical mechanics, the scientific study of motion in the style developed in the seventeenth century by Newton, is often taken as the foundational branch of classical physics. General physics courses commonly begin with the study of motion and use Newtonian mechanics as the setting in which numerous basic concepts, such as energy, force, and momentum, are first introduced.

Physics has long been concerned with understanding the nature and causes of motion. In the tradition of ancient Greek philosophy, the cosmos was thought to be divided into two distinctly differing realms—the terrestrial (near Earth) realm and the celestial realm (the region of the moon and beyond). As conceived in Greek thought, these two realms were not only spatially distinct, but they differed in character from one another in substantial ways. For one thing, the "natural" motions of things (motions that needed no further causation) in these two realms were presumed to be radically different.

According to Aristotle (384–322 B.C.E.), who was for nearly two millennia taken to be the authority on these matters, motion in the terrestrial realm required the continuous application of a cause. Remove the cause, and motion would cease. When a horse ceases to pull a cart, for instance, the cart comes to a halt. In Newton's formulation, however, what requires an active cause is not motion itself, but acceleration—any change in the speed or direction of motion. In effect, Newton's First Law of Motion asserts that the natural motion of things is uniform motion, straight-line motion at constant speed. Any deviation from this—any acceleration, that is—would require a cause. The name for this cause is force—specifically, the force exerted on one object by interaction with another. Expressed more traditionally, Newton's First Law states that unless acted upon by an applied force, an object will continue in a state of rest or uniform motion.

What happens when a force is applied to an object? The answer to that question is the subject of Newton's Second Law of Motion: When acted upon by an applied force, an object will accelerate; the resultant acceleration will be in the same direction as the applied force, and its magnitude will be directly proportional to the magnitude of the applied force and inversely proportional to the object's mass. Stated more succinctly, acceleration is proportional to force divided by mass. This statement, more than any other, functions as the core of Newtonian dynamics, Newton's formulation of the fundamental cause-effect relationship for motion. Force is the cause; acceleration is the effect. For a substantial class of motions, with exceptions to be noted later, this formulation continues to provide a fruitful way to predict or account for acceleration in response to applied forces.

Newton's Third Law of Motion is a statement about the character of the applied forces mentioned in the first two laws. All such forces occur in pairs and are the result of two bodies interacting with one another. When two bodies interact, says Newton, each exerts a force on the other. When bodies A and B interact, the force exerted on A by B is equal in magnitude and opposite in direction to the force exerted on B by A. This is sometimes abbreviated to read, "action equals reaction," but the meanings of *action* and *reaction* must be very carefully specified.

Among the various types of forces that contribute to the acceleration of terrestrial objects is the force of gravity—the force that causes apples, for example, to fall to the ground, or to "accelerate earthward." It was the genius of Newton that allowed him to consider the possibility that the orbital motion of the moon, which entails an acceleration toward the Earth, might also be a consequence of the Earth's gravitational attraction.

This suggestion required a remarkable break with Aristotelian tradition. According to Aristotle, the natural motion of the moon, of the planets, or of any other member of the celestial realm was entirely different from the terrestrial motions considered so far. The natural motion of celestial bodies was neither rest nor uniform straight-line motion. Rather, the motion of celestial bodies would necessarily be based on uniform circular motion, motion at constant speed on a circular path. In the spirit of this assumption, Claudius Ptolemy in the second century crafted a remarkably clever combination of uniform circular motions with which to describe the motions of the sun, moon, and planets relative to the central Earth.

However, building on the fruitful contributions of astronomers Nicolaus Copernicus (1473–1543), Galileo Galilei (1564–1642), and Johannes Kepler (1571–1630), Newton was able to demonstrate that Kepler's sun-centered model for planetary motions could be seen as but one more illustration of Newton's theory regarding the cause-effect relationship for motion. The moon was steered in its orbit around the Earth in response to a force exerted by the Earth on the moon. The Earth and the other planets orbited the sun in response to a force exerted on them by the sun. What was the force operating in these celestial motions? The same kind of force that caused apples to accelerate earthward—the universal gravitational force.

It was helpful to recognize gravity as a force exerted by one object on another. It was exceptionally insightful for Newton to propose that every pair of objects everywhere in the universe exerted gravitational forces on one another. Gone was the confusion of two kinds of natural motions. Gone was the even greater distinction between terrestrial and celestial realms—one characterized by imperfection and change, the other characterized by perfection and constancy. The cosmos is one system, not two. The world is a universe made of one set of substances and behaving according to one set of patterns. Classical mechanics provided the means to study all motions, both terrestrial and celestial, with one and the same methodology.

Classical electromagnetism

Classical electromagnetism provided a systematic account of numerous phenomena involving the interaction of electric charges and currents. Electric charges at rest were considered to be the source of electric fields—modifications in the nature of space that cause other charges to experience a force. Electric charges in motion, giving rise to an electric current, were considered to be the source of magnetic fields, modifications in the nature of space that could be detected by a magnetic compass and caused other electric currents to experience a force. Given any static distribution of electric charge, the configuration of the resultant electric field could be computed. Given any distribution of electric currents, the configuration of the resultant magnetic field could be computed. Given these electric and magnetic field configurations, the forces on all electric charges and currents could be predicted.

In addition to phenomena involving static charge distributions and steady electric currents, another important category of phenomena arises from dynamically changing configurations of charge or current. When charge or current configurations change, the resultant electric and magnetic fields will also change. However, changes in these field configurations must propagate at a finite speed—now called the speed of light, approximately 300,000 kilometers per second. Electromagnetic radiation is the phenomenon of traveling variations, or waves, in electric and magnetic field strength caused by accelerated electric charges. The electromagnetic spectrum spans the full range of wavelength values from very short to very long—from gamma rays, X-rays, and ultraviolet to visible light, infrared, microwaves and radio waves. Maxwell's equations—four mathematical statements that systematically integrated the work of predecessors like Charles-Augustin de Coulomb (1736–1806), Hans Christian Oersted (1777–1851), Michael Faraday (1791–1867), and André-Marie Ampère (1775–1836)—were taken to be the complete specification of all electromagnetic phenomena, including electromagnetic radiation.

Limitations of classical physics

Until the early twentieth century, classical physics appeared to be adequate to account for all observed phenomena. But new discoveries soon demonstrated that, although classical physics would continue to provide a convenient and powerful means of dealing with many phenomena, it needed to be supplemented with other theoretical strategies based on differing sets of assumptions regarding the fundamental character of the physical universe. In the arena of electromagnetism, for instance, classical physics assumed that electromagnetic energy could be continuously varied in value and that its transmission could be fully described in terms of traveling electromagnetic waves. However, in order to account for such phenomena as blackbody radiation (electromagnetic energy radiated by any warm object) and the photoelectric effect (electrons ejected from the surface of a metal illuminated by light), physicists had to propose and accept the idea that electromagnetic energy was transmitted in particle-like quanta of energy, now called *photons.* Phenomena in which the photon character of electromagnetic radiation plays a central role requires the employment of quantum physics in place of classical physics.

Quantum physics is also needed to account for the behavior of extremely small systems like atoms and molecules. The motion of electrons relative to atomic nuclei cannot be adequately described in the language of classical mechanics. Contrary to Newtonian expectations, the energy of atoms and molecules is not continuously variable, but is quantized—restricted to certain specific values. And, contrary to the expectations of classical electromagnetism, electrons in motion relative to atomic nuclei do not radiate energy continuously, but only when making a transition from one stable energy state to another of lower energy value. Consistent with the Principle of Conservation of Energy, the amount of energy lost by the atom is exactly equal to the energy carried away by the emitted photon.

A second shortcoming of classical physics becomes evident when Newtonian mechanics attempts to deal with things that are moving at very high speed relative to an observer. When this speed becomes a substantial fraction of the speed of light, several Newtonian expectations require modification. Many of these modifications are accounted for by the Special Theory of Relativity proposed by Albert Einstein (1879–1955) in 1905. The relationship between kinetic energy (energy associated with motion) and speed must be modified. Distance and time intervals once thought to be invariant become dependent on relative motion. Even the mass of an object is measured differently by different observers. Other modifications are accounted for by Einstein's General Theory of Relativity, published in 1916, which deals with the interaction of mass and the geometry of space. The General Theory describes the force of gravity in a manner very different from Newton's and is able to account for several discrepancies between observation and Newtonian predictions.

Religious concerns and classical physics

Classical physics gave support to the idea that the world was fundamentally deterministic. Given full information about the configuration and motion of some system today, its entire future could, in principle, be computed. Its future was considered to be fully determined by its present. But is there room in such a universe for contingency or choice? The apparent absence of choice presents difficulties for religious concepts like human responsibility and human accountability to God for obedience to revealed standards for moral action.

Another religious concern arises when one inquires about the character and role of divine action in the universe. When Newton considered the future motions of the planets in the solar system, for instance, he judged that this set of orbital motions was inherently unstable and would, from time to time, need to be adjusted by God to restore the desired array of orbits. This introduction of occasional supernatural interventions may be considered a form of the *God of the gaps* approach to divine action: the universe is presumed to lack some quality or capability that must be compensated for by direct divine action. In the case of planetary motions, for example, Newton considered the universe to lack the capability of maintaining a stable set of orbits. This "capability gap" could, however, be bridged with occasional acts of supernatural intervention. Eventually, however, it was demonstrated that the system of planetary orbits was, in fact, stable, thereby removing the need for occasional gap-bridging interventions. When a "gap" of this sort becomes filled, the God of the gaps becomes superfluous. For this reason, many contemporary theologians are inclined to see divine action, not as a supernatural compensation for capability gaps in the universe, but as an essential aspect of an enriched concept of what takes place naturally.

See also ARISTOTLE; DETERMINISM; DIVINE ACTION; GOD OF THE GAPS; GRAVITATION; NEWTON, ISAAC; PHYSICS, QUANTUM; RELATIVITY, GENERAL THEORY OF; RELATIVITY, SPECIAL THEORY OF; WAVE-PARTICLE DUALITY

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HOWARD J. VAN TILL

PHYSICS, PARTICLE

The thought that the bewildering variety of the world might be the result of many different arrangements of certain simple kinds of basic stuff is a very old one. In the sixth century B.C.E., various pre-Socratic philosophers explored such ideas. Thales thought that the fundamental entity might be water, while Anaximenes favored air. Such attempts were both insightful and hopelessly premature. A more sophisticated notion was the atomism introduced by Democritus a century later and promoted with considerable literary skill by the Latin poet Lucretius in the first century B.C.E.

Progress of a recognizably modern kind began with chemist John Dalton's (1766–1844) atomic theory, which introduced in 1803 the notion of atomic weights, derived principally from the properties of gases. Chemist and physician William Prout's (1785–1850) observation in 1815 that most of these weights were near integer multiples of the atomic weight of hydrogen led to what one might call the first true theory of elementary particles, with hydrogen as the conjectured fundamental building block.

Twentieth-century developments

In 1897, physicist Joseph Thomson (1856–1940) convincingly demonstrated that there are light, electrically negative particles (subsequently called *electrons*) that are constituents of what, until then, had been considered to be the indivisible atom. In 1911, physicist Ernest Rutherford (1871–1937) successfully interpreted experiments in which projectiles called *alpha particles* were significantly deflected by a thin gold foil as showing that the positive charge in the atom was concentrated at its center. Rutherford had discovered the nucleus.

In the rest of the twentieth century there followed a series of discoveries, each of which led in turn to a yet deeper conception of the structure of matter, expressed in terms of still smaller constituents playing the role of "elementary" particles. Each phase of these investigations, often pictured metaphorically as peeling another layer off the nuclear "onion," had a sequential form. The process of discovery took place in two parts. The first half consisted in the revelation of an increasing proliferation of putative elementary entities. An example would be the varieties of different nuclei generating the chemical properties of the ninety-two elements of the periodic table. There is a strong conviction in the human mind (exemplified as much by the pre-Socratic philosophers as by twentieth-century physicists) that the fundamental structure of matter should take a simple form, elegant and economical in its character. Proliferation threatens this conviction, but rescue comes in the second half of the process of discovery. Patterns are discerned linking together the proliferating elements, and these patterns are interpreted as reflecting the ways in which a small number of yet more fundamental constituents can be combined. In this way the next level of structure is revealed. It seems fundamental enough until, in turn, it too begins to proliferate, and the cycle begins again.

Thus, nuclei were first recognized as being made up of two kinds of nuclear particles, protons and neutrons. Then experimentalists began to discover many short-lived cousins of these nuclear particles and a proliferation began to threaten. However, the association of these different forms of nuclear matter into certain patterns (called *the eightfold way* by its most insightful investigator, Murray Gell-Mann [b. 1929]) eventually led to the identification of the quark level in the structure of matter.

Consideration of symmetry provides an important mathematical tool for the understanding of pattern formation. For example, the beautiful pattern of a snowflake is due to the sixfold symmetry that leaves it unchanged under a rotation of sixty degrees. It turned out that the patterns of nuclear matter were also generated by symmetry principles, though principles of a more abstract kind than those given by simple rotations in space. Gell-Mann identified the relevant symmetry as being associated with what mathematicians call the group *SU*(3). The *SU*(3) structure involves certain kinds of transformation applied to a set of three basic objects. Such a mathematical fact did not necessarily imply a physical counterpart but, if it did, the corresponding physical entities would generate the next layer in the nuclear onion. Gell-Mann named these entities *quarks.*

There was initially doubt about the physical reality of quarks. The theory requires them to have fractional electric charge ($\frac{2}{3}$; $-\frac{1}{3}$), and no such particles have ever been observed in nature. However, when indirect evidence of their existence came to light, it proved to be very convincing. The experiments involved what is called *deep inelastic scattering*. This is the analogue of the experiments that enabled Rutherford to discover the nucleus, but conducted at much higher energy. Projectiles, such as electrons, when scattered off protons and neutrons, were discovered sometimes to "bounce back" in just the way that they would if they were hitting pointlike quarks lying within these nuclear particles. Physicists could eventually understand why projectiles behaved this way, but in the case of quarks there was a new feature without any precedent in physical experience. However strong the impact of the projectiles, it never proved powerful enough to actually eject a single quark. Eventually, physicists were forced to conclude that quarks were "confined," that is to say, the forces that bound them inside protons and neutrons were always strong enough to overcome the effect of the impact, however great that might be. No one has ever seen an individual quark.

The forces that produce quark confinement are generated by the exchange of further particles that, in the relentlessly jokey terminology endemic in particle physics, are called *gluons.* Further discoveries of exotic kinds of nuclear matter increased the number of types of quark from three to six. These ideas, together with others of a more technical character, constitute what has come to be called the *Standard Model.*

Only one piece in the jigsaw that defines the standard model is still missing. This is the particle proposed by Peter Higgs as the source of mass within the theory. Particle accelerators can yield energies that are just on the border of where this Higgs particle (as it is called) may be expected to show up. Establishing its existence would be extremely satisfying.

The Standard Model describes very well the properties of subnuclear matter but, with its six varieties of quark and with other somewhat inelegant elaborations, there is an air of proliferation about it. Most physicists, therefore, do not feel a final satisfaction with the Standard Model. There are two ways in which one might hope eventually to go beyond it. One is the discovery of a *Grand Unified Theory* (GUT).

In terms of directly observed phenomena there seem to be four basic forces of nature: strong nuclear forces (holding nuclei together); electromagnetic forces (holding atoms and bulk matter together); weak nuclear forces (causing matter to decay); and gravity. One of the triumphs of the Standard Model was to show that two of these forces, electromagnetic and weak, are in reality aspects of a single phenomenon, a fact that becomes clear experimentally at very high energies. Physicists believe that at even higher energies (such as would be present in the very early universe) these two forces would unite with the strong nuclear force to give a GUT. The detailed form this theory might be expected to take has not been established.

At higher energies still, there is the possibility that gravity and the GUT unite. For technical reasons, however, a theory of this super-unified kind is even harder to formulate than a GUT. The best speculative prospect appears to be superstring theory (or its generalizations), in which quarks and electrons are pictured as modes of vibration of extremely tiny strings oscillating in many dimensions, all but four of which (space and time) are "rolled up" out of empirical sight.

Lessons for theology

Particle physics is methodologically the most reductionist form of physics. It encourages the thought of constituent reductionism, implying that were a human being to be decomposed into bits and pieces, the ultimate result would be an immense collection of quarks, gluons, and electrons. This observation, however, by no means proves that human beings are nothing but collections of elementary particles, since such a decomposition would kill the person. In fact, quantum physics encourages an antireductionist stance, because it has been shown that there is a counterintuitive mutual entanglement of quantum entities, even when they are spatially separated (the EPR effect). It does not seem that even the subatomic world can be treated purely atomistically.

An important technique of discovery in fundamental physics has proved to be the search for equations endowed with the unmistakable quality of mathematical beauty. Paul Dirac (1902–1984), one of the founding figures of quantum mechanics, once expressed the opinion that it was more important to have mathematical beauty in one's equations than to have them fit experiment. Of course, he did not mean that empirical adequacy is irrelevant to physics, but apparent failure to fit experiment might be due to a number of reasons, such as making an incorrect approximation in solving the equations, or even to the experimental results themselves being wrong. But if the equations were ugly, there was really no hope, for ugliness ran counter to everything that experience of fundamental physical theory had led one to expect. Dirac made his own significant discoveries through just such a quest for mathematical beauty, and the same principle is the guiding strategy followed by the bold proponents of superstring theory. It seems that the physical world is not only rationally transparent to our enquiry, it is also rationally beautiful. Beneath the vast variety of everyday objects, at the subatomic level there is a fundamental structure that is intellectually exciting in its simplicity and profoundly satisfying in the elegance and economy of its order. The reward for doing particle physics is the sense of wonder at its discoveries. The theistic religious believer will readily see the mind of the Creator behind the rationally beautiful order of the physical world.

Another lesson one may learn from particle physics is that human powers of rational prevision are severely limited. Time and again, nature has proved surprising as it resists our prior expectations. In the 1950s, particle physicists who were attempting to make sense of certain weak decays faced profound difficulties. After much fruitless struggle, the situation was transformed and made intelligible when in 1956 two physicists, Tsung Dao Lee and Chen Ning Yang, proposed the abandonment of what had been a cherished belief of particle physicists. Until then, it had been an article of faith that there could be no intrinsic handedness in nature, meaning that fundamental processes should show no preference for right-handed versions over left-handed versions or—putting it another way—that the laws of physics seen in a mirror should look exactly the same as the laws of physics observed directly. This supposed property was called the *conservation of parity,* and it was believed to be a self-evident truth about nature. Lee and Yang showed that this was not so, a discovery for which they rightly and promptly received the Nobel Prize.

Particle physics teaches us that the physical world is extremely surprising. It would be strange if that were not also true of human encounter with the much deeper mystery of divine reality. Physicists do not favor the question "Is it reasonable?" with its tacit presumption that one knows beforehand what form rationality should take. Rather, they ask the more open question "What makes you think this might be the case?" Theology too can benefit from seeking belief motivated by experience rather than by a priori expectation.

Finally, particle physicists believe in unseen realities (quarks) because such a belief makes sense of great swathes of physical experience. For them, it is intelligibility that affords the clue to existence. This does not seem altogether different from the reasons for theology's belief in the unseen reality of God.

See also FORCES OF NATURE; GRAND UNIFIED THEORY; STRING THEORY; SUPERSTRINGS; SYMMETRY

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JOHN POLKINGHORNE

PHYSICS, QUANTUM

Quantum theory is one of the most successful theories in the history of physics. The accuracy of its predictions is astounding. The breath of its application is impressive. Quantum theory is used to explain how atoms behave, how elements can combine to form molecules, how light behaves, and even how black holes behave. There can be no doubt that there is something very right about quantum theory.

But at the same time, it is difficult to understand what quantum theory is really saying about the world. In fact, it is not clear that quantum theory gives any consistent picture of what the physical world is like. Quantum theory seems to say that light is both wavelike and particlelike. It seems to say that objects can be in two places at once, or even that cats can be both alive and dead, or neither alive nor dead, or—what? There can be no doubt that there is something troubling about quantum theory.

Early research

Quantum theory, more or less as it is known at the beginning of the twenty-first century, was developed during the first quarter of the twentieth century in response to several problems that had arisen with classical mechanics. The first is the problem of blackbody radiation. A *blackbody* is any physical body that absorbs all incident radiation. As the blackbody continues to absorb radiation, its internal energy increases until, like a bucket full of water, it can hold no more and must re-emit radiation equal in energy to any additional incident radiation. The problem is, most simply, that the classical prediction for the energy of the emitted radiation as a function of its frequency is wrong. The problem was well known but unsolved until the German physicist Max Planck (1858–1947) proposed in 1900 the hypothesis that the energy absorbed and emitted by the blackbody could come only in discrete amounts, multiples of some constant, finite, amount of energy. While Planck himself never felt satisfied with this hypothesis as more than a localized, phenomenological description of the behavior of blackbodies, others eventually accepted Planck's hypothesis as a revolution, a claim that energy itself can come in only discrete amounts, the *quanta* of quantum theory.

A second problem with classical mechanics was the challenge of describing the spectrum of hydrogen, and eventually, other elements. Atomic spectra are most easily understood in light of a fundamental formula linking the energy of light with its frequency: $E = h\nu$, where E is the energy of light, h is a constant (Planck's constant, as it turns out), and ν is the frequency of the light (which determines the color of the visible light).

Suppose, now, that the energy of some atom (for example, an atom of hydrogen) is increased. If the atom is subsequently allowed to relax, it releases the added energy in the form of (electromagnetic) radiation. The relationship $E = h\nu$ reveals that the frequency of the light depends on the amount of energy that the atom emits as it relaxes. Prior to the development of quantum theory, the best classical theory of the atom was Ernest Rutherford's (1871–1937), according to which negatively charged electrons orbit a central positively charged nucleus. The energy of a hydrogen atom (which has only one electron) corresponds to the distance of the electron from the nucleus. (The further the electron is, the higher its energy is.) Rutherford's model predicts that the radiation emitted by a hydrogen atom could have any of a continuous set of possible energies, depending on the distance of its electron from the nucleus. Hence a large number of hydrogen atoms with energies randomly distributed among them will emit light of many frequencies. However, in the nineteenth century it was well known that hydrogen emits only a few frequencies of visible light.

In 1913, Niels Bohr (1885–1962) introduced the hypothesis that the electrons in an atom can be only certain distances from the nucleus; that is, they can exist in only certain "orbits" around the nucleus. The differences in the energies of these orbits correspond to the possible energies of the radiation emitted by the atom. When an electron with high energy "falls" to a lower orbit, it releases just the amount of energy that is the difference between the energies of the higher and lower orbits. Because only certain orbits are possible, the atom can emit only certain frequencies of light.

The crucial part of Bohr's proposal is that electrons cannot occupy the space between the orbits, so that when the electron passes from one orbit to another, it "jumps" between them without passing through the space in between. Thus, Bohr's model violates the principle of classical mechanics that particles always follow continuous trajectories. In other words, Bohr's model left little doubt that classical mechanics had to be abandoned.

Over the next twelve years, the search was on for a replacement. By 1926, as the result of considerable experimental and theoretical work on the part of numerous physicists, two theories—experimentally equivalent—were introduced, namely, Werner Heisenberg's (1901–1976) *matrix mechanics* and Erwin Schrödinger's (1887–1961) *wave mechanics.*

Matrix mechanics. Heisenberg's matrix mechanics arose out of a general approach to quantum theory advocated already by Bohr and Wolfgang Pauli (1900–1958), among others. In Heisenberg's hands, this approach became a commitment to remove from the theory any quantities that cannot be observed. Heisenberg took as his "observable" such things as the transition probabilities of the hydrogen atom (the probability that an electron would make a transition from a higher to a lower orbit). Heisenberg introduced operators that, in essence, represented such observable quantities mathematically. Soon thereafter, Max Born (1882–1970) recognized Heisenberg's operators as matrices, which were already well understood mathematically.

Heisenberg's operators can be used in place of the continuous variables of Newtonian physics. Indeed, one can replace Newtonian position and momentum with their matrix "equivalents" and obtain the equations of motion of quantum theory, commonly called (in this form) *Heisenberg's equations.* The procedure of replacing classical (Newtonian) quantities with the analogous operators is known as *quantization.* A complete understanding of quantization remains elusive, due primarily to the fact that quantum-mechanical operators can be incompatible, which means in particular that they cannot be comeasured.

Wave mechanics. Schrödinger's wave mechanics arose from a different line of reasoning, primarily due to Louis de Broglie (1892–1987) and Albert Einstein (1879–1955). Einstein had for some time expressed a commitment to a physical world that can be adequately described causally, which meant that it could be described in terms of quantities that evolve continuously in time. Einstein, who was primarily responsible for showing that light has both particlelike and wavelike properties, hoped early on for a theory that somehow "fused" these two aspects of light into a single consistent theory.

In 1923, de Broglie instituted the program of wave mechanics. He was impressed by the Hamilton-Jacobi approach to classical physics, in which the fundamental equations are wave equations, but the fundamental objects of the theory are still particles, whose trajectories are determined by the waves. Recalling this formalism, de Broglie suggested that the particlelike and wavelike properties of light might be reconcilable in similar fashion. Einstein's enthusiasm for de Broglie's ideas—both because de Broglie's waves evolved continuously and because the theory fused the wavelike and particlelike properties of light and matter—stimulated Schrödinger to work on the problem from that point of view, and in 1926 Schrödinger published his wave mechanics.

It was quickly realized that matrix mechanics and wave mechanics are experimentally equivalent. Shortly thereafter, in 1932, John von Neumann (1903–1957) showed their equivalence rigorously by introducing the Hilbert space formalism of quantum theory. The Uncertainty Principle serves to illustrate the equivalence. The Uncertainty Principle follows immediately from Heisenberg's matrix mechanics. Indeed, in only a few lines of argument, one can arrive at the mathematical statement of the Uncertainty Principle for any operators (physical quantities) A and B: $\Delta A \Delta B \geq Kh$, where K is a constant that depends on A and B, and h is Planck's constant. The symbol ΔA means "root mean square deviation of A" and is a measure of the statistical dispersion (uncertainty) in a set of values of A. So the Uncertainty Principle says that the statistical dispersion in values of A times the statistical dispersion in values of B are always greater than or equal to some constant. If (and only if) A and B are incompatible (see above) then this constant is greater than zero, so that it is impossible to measure a both A and B on an ensemble of physical systems in such a way as to have no dispersion in the results.

Schrödinger's wave mechanics gives rise to the same result. It is easiest to see how it does so in the context of the classic example involving position and momentum, which are incompatible quantities. In the context of Schrödinger's wave mechanics, the probability of finding a particle at a given location is determined by the amplitude (height) of the wave at that location. Hence, a particle with a definite position is represented by a "wave" that is zero everywhere except at the location of the particle. On the other hand, a particle with definite momentum is represented by a wave that is flat (i.e., has the same amplitude at all points), and, conversely to position, momentum becomes more and more "spread" as the wave becomes more sharply peaked. Hence the more precisely one can predict the location of a particle, the less precisely one can predict its momentum. A more quantitative version of these considerations leads, again, to the Uncertainty Principle.

Quantum field theory. Perhaps the major development after the original formulation of quantum theory by Heisenberg and Schrödinger (with further articulation by many others) was the extension of quantum mechanics to fields, resulting in quantum field theory. Paul Dirac (1902–1984) and others extended the work to relativistic field theories. The central idea is the same: The quantities of classical field theory are quanticized in an appropriate way. Work on quantum field theory is ongoing, a central unresolved issue being how one can incorporate the force of gravity, and specifically Einstein's relativistic field theory of gravity, into the framework of relativistic quantum field theory. A related, though even more speculative, area of research is quantum cosmology, which is, more or less, the attempt to discern how Big Bang theory (itself derived from Einstein's Theory of Gravity) will have to be modified in the light of quantum gravity.

Contemporary research

Contemporary research in the interpretation of quantum theory focuses on two key issues: the "measurement problem" and locality (Bell's Theorem).

Schrödinger's cat. Although the essence of the measurement problem was clear to several researchers even before 1925, it was perhaps first clearly stated in 1935 by Schrödinger. In his famous example, Schrödinger imagines a cat in the following unfortunate situation. A box, containing the cat, also contains a sample of some radioactive substance that has a probability of 1/2 to decay within one hour. Any decay is detected by a Geiger counter, which releases poison into the box if it detects a decay. At the end of an hour, the state of the cat is indeterminate between "alive" and "dead," in much the same way that a state of definite position is indeterminate with regard to momentum.

The cat is said to be in a *superposition* of the alive state and the dead state. In standard quantum theory, such a superposition is interpreted to mean that the cat is neither determinately alive, nor determinately dead. But, says Schrödinger, while one might be able to accept that particles such as electrons are somehow indeterminate with respect to position or momentum, one can hardly accept indeterminacy in the state of a cat.

More generally, Schrödinger's point is that indeterminacy at the level of the usual objects of quantum theory (electrons, protons, and so on) can easily be transformed into indeterminacy at the level of everyday objects (such as cats, pointers on measuring apparatuses, and so on) simply by coupling the state of the everyday object to the state of the quantum object. Such couplings are exactly the source of our ability to measure the quantum objects in the first place. Hence, the problem that Schrödinger originally raised with respect to the cat is now called the *measurement problem*: Everyday objects such as cats and pointers can, according to standard quantum theory, be indeterminate in state. For example, a cat might be indeterminate with respect to whether it is alive. A pointer might be indeterminate with respect to its location (i.e., it is pointing in no particular direction).

Approaches to the measurement problem. Thus, the interpretation of quantum theory faces a serious problem, the measurement problem, to which there have been many approaches. One approach, apparently advocated by Einstein, is to search for a *hidden-variables* theory to underwrite the probabilities of standard quantum theory. The central idea here is that the indeterminate description of physical systems provided by quantum theory is incomplete. Hidden variables (so-called because they are "hidden" from standard quantum theory) complete the quantum-mechanical description in a way that renders the state of the system determinate in the relevant sense. The most famous example of a successful hidden-variables theory is the 1952 theory of David Bohm (1917–1992), itself an extension of a theory proposed by Louis de Broglie in the 1920s. In the Broglie-Bohm theory, particles always have determinate positions, and those positions evolve deterministically as a function of their own initial position and the initial positions of all the other particles in the universe. The probabilities of standard quantum theory are obtained by averaging over the possible initial positions of the particles, so that the probabilities of standard quantum theory are due to ignorance of the initial conditions, just as in classical mechanics. According to some, the problematic feature of this theory is its *nonlocality*—the velocity of a given particle can depend instantaneously on the positions of particles arbitrarily far away.

Other hidden-variables theories exist, both deterministic and indeterministic. They have some basic features in common with the de Broglie-Bohm theory, although they do not all take position to be "preferred"—some choose other preferred quantities. In the de Broglie-Bohm theory, position is said to be "preferred" because all particles always have a definite position, by stipulation.

There are other approaches to solving the measurement problem. One set of approaches involves so-called *Many-worlds* interpretations, according to which each of the possibilities inherent in a superposition is in fact actual, though each in its own distinct and independent "world." There is a variant, the *Many-minds* theory, according to which each observer observes each possibility, though with distinct and independent "minds."

These interpretations have a notoriously difficult time reproducing the probabilities of quantum theory in a convincing way. A slightly more technical, but perhaps even more troubling, issue arises from the fact that any superposition can be "decomposed" into possibilities in an infinity of ways. So, for example, a superposition of "alive" and "dead" can also be decomposed into other pairs of possibilities. It is unclear how Many-worlds interpretations determine which decomposition is used to define the "worlds," though there are various proposals.

Yet another set of approaches to the measurement problem is loosely connected to the Copenhagen Interpretation of quantum theory. According to these approaches, physical quantities have meaning only in the context of an experimental arrangement designed to measure them. These approaches insist that the standard quantum-mechanical state is considered to describe our ignorance about which properties a system has in cases where the possible properties are determined by the experimental context. Only those properties that could be revealed in this experimental context are considered "possible." In this way, these interpretations sidestep the issue of which decomposition of a superposition one should take to describe the possibilities over which the probabilities are defined. Once a measurement is made, the superposition is "collapsed" to the possibility that was in fact realized by the measurement. In this context, the collapse is a natural thing to do, because the quantum mechanical state represents our ignorance about which experimental possibility would turn up. The major problem facing these approaches is to define *measurement* and *experimental context* in a sufficiently rigorous way.

Another set of approaches are the *realistic collapse* proposals. Like the Copenhagen approaches, they take the quantum-mechanical state of a system to be its complete description, but unlike them, these approaches allow the meaningfulness of physical properties even outside of the appropriate experimental contexts. The issue of how to specify when collapse will occur is thus somewhat more pressing for these approaches because the collapse represents not a change in our knowledge, but a physical change in the world. There are several attempts to provide an account of when collapse will occur, perhaps the two most famous being *observer-induced* collapse and *spontaneous localization* theories. According to the former, notably advocated by Eugene Wigner (1902–1995), the act of observation by a conscious being has a real effect on the physical state of the world, causing it to change from a superposition to a state representing the world as perceived by the conscious observer. This approach faces the very significant problem of explaining why there should be any connection between the act of conscious observation and the state of, for example, some electron in a hydrogen atom.

The spontaneous-localization theories define an observer-independent mechanism for collapse that depends, for example, on the number of particles in a physical system. For low numbers of particles the rate of collapse is very slow, whereas for higher values, the rate of collapse is very high. The collapse itself occurs continuously, by means of a randomly distributed infinitesimal deformation of the quantum state. The dynamics of the collapse are designed to reproduce the probabilities of quantum theory to a very high degree of accuracy.

The problem of nonlocality. The other major issue facing the interpretation of quantum theory is *nonlocality.* In 1964, John Bell (1928–1990) proved that, under natural conditions, any interpretation of quantum theory must be nonlocal. More precisely, in certain experimental situations, the states of well-separated pairs of particles are correlated in a way that cannot be explained in terms of a common cause. One can think, here, of everyday cases to illustrate the point. Suppose you write the same word on two pieces of paper and send them to two people, who open the envelopes simultaneously and discover the word. There is a correlation between these two events (they both see the same word), but the correlation is easily explained in terms of a common cause, you.

Under certain experimental circumstances, particles exhibit similar correlations in their states, and yet those correlations cannot be explained in terms of a common cause. It seems, instead, that one must invoke nonlocal explanations, explanations that resort to the idea that something in the vicinity of one of the particles instantaneously influences the state of the other particle, even though the particles are far apart.

On the face of it, nonlocality contradicts special relativity. According to standard interpretations of the theory of relativity, causal influences cannot travel faster than light, and in particular, events in one region of space cannot influence events in other regions of space if the influence would have to travel faster than light to get from one region to the other in time to influence the event.

However, the matter is not so simple as a direct contradiction between quantum theory and relativity. The best arguments for the absence of faster-than-light influences in relativity are based on the fact that faster-than-light communication—more specifically, transfer of information—can lead to causal paradoxes. But in the situations to which Bell's theorem applies, the purported faster-than-light influences cannot be exploited to enable faster-than-light communication. This result is attributable to the indeterministic nature of standard quantum theory. In de Broglie and Bohm's deterministic hidden-variable theory, one could exploit knowledge of the values of the hidden variables to send faster-than-light signals; however, such knowledge is, in Bohm's theory, physically impossible in principle.

Other areas of research. There are of course many other areas of research in the interpretation of quantum theory. These include traditional areas of concern, such as the classical limit of quantum theory. How do the nonclassical predictions of quantum theory become (roughly) equivalent to the (roughly accurate) predictions of classical mechanics in some appropriate limit? How is this limit defined? In general, what is the relationship between classical and quantum theory? Other areas of research arise from work in quantum theory itself, perhaps the most notable being the work in quantum computation. It appears that a quantum computer could perform computations in qualitatively faster time than a classical computer. Apart from obvious practical considerations, the possibility of quantum computers raises questions about traditional conceptions of computation, and possibly, thereby, about traditional philosophical uses of those conceptions, especially concerning the analogies often drawn between human thought and computation.

Applications to religious thought

Quantum theory was the concern of numerous religious thinkers during the twentieth century. Given the obviously provisional status of the theory, not to mention the extremely uncertain state of its interpretation, one must proceed with great caution here, but we can at least note some areas of religious thought to which quantum theory, or its interpretation, has often been taken to be relevant.

Perhaps the most obvious is the issue of whether the world is ultimately deterministic or not. Several thinkers, including such scientists as Isaac Newton (1642–1727) and Pierre-Simon Laplace (1749–1827), have seen important ties to religious thought. In the case of classical mechanics, Newton had good reason to believe that his theory did not completely determine the phenomena, whereas Laplace (who played a key role in patching up the areas where Newton saw the theory to fail) had good reason to think that the theory did completely and deterministically describe the world. Newton thus saw room for God's action in the world; Laplace did not.

In the case of quantum theory the situation is considerably more difficult because there exist both indeterministic and deterministic interpretations of the theory, each of which is empirically adequate. Indeed, they are empirically equivalent. Those who, for various reasons, have adopted one or the other interpretation, though, have gone on to investigate the consequences for religious thought. Some, for example, see in quantum indeterminism an explanation of the possibility of human free will. Others have suggested that quantum indeterminism leaves an important role for God in the universe, namely, as the source of the agreement between actual relative frequencies and the probabilistic predictions of quantum theory.

Other thinkers have seen similarities between aspects of quantum theory and Eastern religions, notably various strains of Buddhism and Daoism. Fritjof Capra (1939–), who is perhaps most famous in this regard, has drawn analogies between issues that arise from the measurement problem and quantum nonlocality and what he takes to be Eastern commitments to the "connectedness" of all things. Other thinkers have seen in the interpretive problems of quantum theory evidence of a limitation in science's ability to provide a comprehensive understanding of the world, thus making room for other, perhaps religious, modes of understanding. Still others, drawing on views such as Wigner's (according to which conscious observation plays a crucial role in making the world determinate), see in quantum theory a justification of what they take to be traditional religious views about the role of conscious beings in the world. Others, including Capra, see affinities between wave-particle duality, or more generally, the duality implicit in the Uncertainty Principle, and various purportedly Eastern views about duality (for example, the Taoist doctrine of yin and yang, or the Buddhist use of koans).

Finally, quantum cosmology has provided some with material for speculation. One must be extraordinarily careful here because there is, at present, no satisfactory theory of quantum gravity, much less of quantum cosmology. Nonetheless, a couple of (largely negative) points can be made. First, it is clear that the standard Big Bang theory will have to be modified, somehow or other, in light of quantum theory. Hence, the considerable discussion to date of the religious consequences of the Big Bang theory will also need to be reevaluated. Second, due to considerations that arise from the time-energy Uncertainty Principle, even a satisfactory quantum cosmology is unlikely to address what happened in the early universe prior to the Planck time (approximately 10^{-43} seconds) because quantum theory itself holds that units of time less than the Planck time are (perhaps) meaningless. Some have seen here a fundamental limit in scientific analysis, a limit that is implied by the science itself. Of course, others see an opportunity for a successor theory.

This situation is, in fact, indicative of the state of quantum theory as a whole. While it is an empirically successful theory, its interpretations, and hence any consequences it might have for religious thought, remain matters of speculation.

See also COPENHAGEN INTERPRETATION; EPR PARADOX; HEISENBERG'S UNCERTAINTY PRINCIPLE; INDETERMINISM; LOCALITY; MANY-WORLDS HYPOTHESIS; PHASE SPACE; PLANCK TIME; QUANTUM COSMOLOGIES; QUANTUM FIELD THEORY; SCHRÖDINGER'S CAT; WAVE-PARTICLE DUALITY

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PLACEBO EFFECT

Although the term *placebo effect* might appear logically to refer to "the effect produced by a placebo," that definition is not in fact the one most commonly used. It would be more accurate to define the *placebo effect* as "the mind-body interaction triggered by medical treatment, historically discovered as a result of placebo use." That is, medical science may first have learned about the potential impact of the patient's mental state on healing by observing the effects of *placebos* ("dummy" or "sham" therapies thought to be lacking in any ingredients capable of producing bodily changes by chemical or physical means). If patients' bodies and symptoms were altered in impressive ways after the administration of placebos, the absence of any chemical explanation for the change suggested that it could only be by means of the patients' minds that such changes occurred. Once this basic observation is made, one may go on to divorce the patients' mental state from the use of dummy or sham remedies. Virtually any aspect of the encounter with a physician or other health worker could stimulate the requisite mental state, whether that state is one of expecting that one will get better, feeling trust in the caregiver, or whatever the precise psychological mechanism may be. It is in keeping with most modern usage to define *placebo effect* as "a change in a person's health status attributable to the symbolic or emotional impact of a healing intervention."

History

Ancient Greek medicine and the humoral medicine of the Middle Ages and Renaissance simply took for granted that words had the power to both cause or cure disease and that the mind and the body were constantly interacting to determine the individual's state of health. The earliest known reference to deliberate use of a placebo appears in a 1580 essay by Montaigne (1533–1592) describing a hypochondriac who was cured by an enema administered with great fanfare but without any substance actually being injected into the body. It is almost certain, however, that the use of placebos in medicine antedates this essay, probably by many centuries.

Medical science underwent a more materialistic turn and began to ignore the mind during the nineteenth century, but even then, citations appeared in the medical literature testifying to the power of placebos, and to the imagination generally, to alter disease. Placebos were frequently administered in the nineteenth century, in part because the profession lacked more effective medicines for most diseases.

Benjamin Franklin (1706–1790) was one of the first to use a *single-blind* technique in experiments on the power of mesmerism (hypnosis) conducted in 1785. Franklin was able to show by concealing the hypnotist behind a curtain that subjects' reactions were based on what they thought was happening and not on what was actually happening. Medicine increasingly demanded a blind technique when investigating "unconventional" or "quack" remedies in the nineteenth century but resisted the idea that conventional medical drugs and other remedies ought to be subjected to the same methods. After World War II, medical scientists became more aware of the potential for bias to skew research results if either the subject of the experiment, or the physician observing the experiment, knew who was receiving the "true" medicine, so the *double-blind* design, with neither party knowing which subject got the study medication and which got the placebo, gradually was adopted as the standard of valid research. Thus, precisely when placebos were less often used in medical practice (because so many powerful new drugs were available), placebos began to be used much more often as a research tool.

Modern medical ethics demands frank disclosure to the patient of the nature of any treatment administered. This, in most cases, rules out the deceptive use of placebos in therapy. But ethics does not rule out the attempt to elicit a placebo effect by creating a positive emotional environment during interaction with the patient. After largely dismissing the mind for many decades as largely unimportant and resistant to scientific study, modern medical science has developed a renewed interest in understanding the mechanisms by which the placebo effect might work. In 2001, the U.S. National Institutes of Health announced a new research program specifically aimed at understanding the mechanisms of the placebo effect and helping practicing physicians to enhance the effect.

Scientific understanding

Two psychological mechanisms appear to contribute to the placebo effect: *expectancy* (believing that a positive bodily change will occur) and *conditioning* (being in circumstances that, in the past, produced a positive bodily change). Evidence is accumulating that expectancy of pain relief can produce the release of endorphins, naturally occurring morphine-like chemicals in the brain that produce analgesia. In one study, when patients in pain following surgery were given a visible injection of a narcotic painkiller into their intravenous tubing, they experienced twice as much pain relief as when the same drug was given by hidden injection and the patient was unaware of receiving the drug. When naloxone, a drug that antagonizes the effects of endorphins, is administered to patients in the same manner, the placebo effect can be reversed.

Modern brain imaging techniques promise to expand the understanding of the mechanisms of the placebo effect. Using positron emission tomography (PET) scanning, for instance, patients experiencing a placebo effect in Parkinson's disease were shown to be manufacturing more dopamine in their brains, indicating that the placebo effect in Parkinson's may work by the same biochemical mechanism as the standard drug therapy.

Amidst new findings on how the placebo effect works, some skeptics continue to question whether the effect even exists. A systematic review of 114 randomized double-blind clinical trials (Hróbjartsson and Gøtzsche, 2001) concluded that there is no good evidence that administering placebos in the context of scientific trials produces any significant change in the subjects. (The authors did not intend their findings to address whether the placebo effect might exist in actual medical practice.) The methods used in this review have been challenged by placebo-effect advocates. Regardless, an important lesson from skeptical research such as this is that there are many mimics whose effects must be carefully separated from true placebo effects. Perhaps the most common mimic is the natural history of the illness, or the body's inherent healing powers. Many older studies that are quoted as confirming a powerful placebo effect in fact failed to distinguish between the patient's getting better because the illness was self-limited and the body's defenses were capable of eliminating it (as is the case with most common viral illnesses) and improvement that truly depended on the patient's mental or emotional state.

Implications for religion

Placebo effects may be of greatest interest in one category of so-called complementary and alternative medicine (CAM): methods of healing that rely particularly on religious faith or religious practices.

Religiously-based healing might be thought, by believers, to occur in one of two ways. In what one might call the *natural* route, faith, prayer, or other religious practices may be seen as stimulating the same chemical and physical processes in the human body as would be produced by any other system of medicine or healing. In what one might term the *supernatural* route, faith or prayer comes directly from a divine source and does not depend solely upon processes that science can measure or understand.

In religious healing by the natural route, the placebo effect could account for some and perhaps all of the healing observed. Faith and prayer may produce positive expectancies, and religious ritual may be a powerful source of psychological conditioning. So long as one believes that the human mind is part of the natural world, molded by the same creator who is responsible for any other healing modality, it seems logical that one would seek to harness the powers of the mind as part of whatever healing occurs. On this understanding the placebo effect becomes simply one means by which faith can heal.

In religious healing by the supernatural route, it might appear by contrast that if one could show that a placebo effect were occurring, that would exclude the possibility of the postulated healing effect. This seems particularly true for studies of intercessory prayer, in which believers claim that patients can be healed when people pray for them unbeknownst to the patients themselves. By definition, no emotional or mental effect can be generated if the subjects are completely unaware of the intervention. Therefore, to claim that the results of intercessory prayer are a placebo effect would be the same as denying that intercessory prayer works.

Another important implication of the placebo effect for religious healing is shared with other types of CAM: the design of appropriate comparison groups to conduct reliable research. What counts as adequate evidence that any form of CAM, including religious or faith healing, works? Some scientists reject all CAM out of hand as based on superstition and quackery, but more careful scientists are willing to accept CAM insofar as it can be shown to be effective in rigorous scientific studies. The question then arises as to what counts as adequate scientific "rigor" given the subject matter under study.

One way to approach this concern is to view science as a highly systematic way to show with a high level of probability that one explanation is the correct explanation for the phenomenon in which we are interested. Showing this requires that we consider all other plausible explanations and find ways to exclude them, so that we are left with only one explanation that appears to be correct. This is what it means in general terms to have a controlled study. It follows from this analysis that having a placebo or sham-treatment control group is one good way to eliminate several plausible explanations for healing. A placebo control group can eliminate the placebo effect, the natural course of illness, and a number of chance statistical associations as reasons why the subjects receiving the healing intervention got better. Because the placebo control is useful for many study purposes, it is tempting to assume that the only valid scientific study is one with a placebo control, but this would be mistaken. Depending on the question being investigated and which alternative explanations are most plausible, there may be other scientific methods to exclude the alternative explanations with a high degree of reliability. In many possible studies of religious healing, the usual methods to assure scientific rigor will simply not be possible. It is hard, for example, to imagine a population of both believers and nonbelievers agreeing to be assigned randomly to receive real or sham faith-healing.

See also MEDICINE; MIND-BODY THEORIES;
SPIRITUALITY AND HEALTH

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PLANCK TIME

The Planck time is a unit of time that is defined by three of the fundamental constants of nature: Isaac Newton's constant of gravitation, G; the velocity of light in vacuum, c; and Max Planck's constant, h. These constants may be combined in one and only one way to give a quantity that has the dimensions of a time:

$$t_{\text{PLANCK}} = (Gh/c^5)^{1/2} = 1.3 \times 10^{-43}\ s$$

This unit of time exists independently of all human standards of time measurement. It is defined by the gravitational, relativistic, and quantum aspects of the universe. The universe can be said to be "old" in the well defined sense that it is about 10^{60} Planck times in age (about thirteen billion years). The Planck time has cosmological significance. It marks the time before which the entire universe displays wave-particle duality. In order to understand events earlier than the Planck time, quantum cosmology is required. The Planck time was first identified by German theoretical physicist Max Planck (1858–1947) in 1899, although the idea of a natural unit of time based on the fundamental constants G, c, and e (the charge on the electron) was first presented by Irish physicist George Johnstone Stoney (1826–1911) in 1881.

See also AGE OF THE UNIVERSE; COSMOLOGY, PHYSICAL ASPECTS; PHYSICS, QUANTUM

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PLATO

In his written dialogues, Plato developed accounts of knowledge, reality, humanity, society, goodness, God, and beauty. Usually, when people speak of Platonism, they are referring to his theory of Forms, accompanied by a doctrine of the immortality of the soul and values that transcend power, prestige, and pleasure. Western thought has developed either by following and adapting his accounts or by reacting to them, either directly or indirectly through, most notably, Aristotle, Plotinus, Philo, and Augustine. The theory of Forms established the most basic concept of science as it came to be practiced in Europe, namely, that science aims to discover objective principles, in other words, "Forms." Plato's doctrine of the immortality of the soul and values that transcend the material world have reinforced and shaped systematic thinking within Judaism, Christianity, and Islam.

Life and times

Plato (428–347 B.C.E.) was born in Athens to a rich and politically powerful family. Instead of taking his place in the ruling class, he became a philosopher. He founded the Academy and invented a new form of literature, the dramatic dialogue. His dialogues, featuring the philosopher Socrates (469–399 B.C.E.), have profoundly shaped history, in a way comparable to the writings of Paul about Jesus.

Plato chose philosophy because he fell under the spell of Socrates as a young man while witnessing the horrors of political life in his time and city. At the time of Plato's birth, Athens, a city-state in Greece, was the world's first democracy, inventing such wonders as trial by jury, as well as some of the greatest sculpture, architecture, and drama of any age. But during this time of extraordinary human achievement, the wisest man of all, as confirmed by a religious oracle, was one who professed to have no wisdom at all: Socrates. Socrates would closely question people who professed to know politics, religion, or any deep wisdom about life, and he would show that their pretenses to wisdom were false. Socrates would also use his chains of questions to lead anyone who would speak with him to agree human excellence was exclusively a matter of wisdom, and that the search for wisdom was the best way to spend one's life.

Plato was fascinated by Socrates and joined other young men in spending time in his company. At the same time Plato observed how demagogues led Athens to prolong its Peloponnesian War (431–404 B.C.E.) against Sparta, a war that ended in utter defeat for Athens. The Spartans installed an antidemocratic government that included members of Plato's family. This government ruled murderously, but briefly, until a citizens' armed rebellion restored the democracy, although Athens's empire and military preeminence were gone forever. Under this same democracy, just a couple of years later (399 B.C.E.), a religiously conservative prosecutor brought Socrates to trial on charges of atheism, heresy, and corrupting the young. The jury found Socrates guilty and sentenced him to death. It is no wonder that Plato became disillusioned with a life aimed at political rule, and decided instead to devote his life to developing Socrates's ideas.

Plato spent his time in private conversations with friends about Socrates' ideas, honoring his memory by continuing to seek wisdom. Some of these friends were Pythagoreans. Pythagoras lived about a hundred years before Plato in Greek colonies in the south of Italy. According to reports, Pythagoras had supernatural powers and formed a religious school of followers. He believed that human souls are reincarnated in animal and human bodies. Pythagoras also was aware of the mathematical structure of musical harmony and believed that numbers provide the explanation of all the order in the universe. Plato traveled to southern Italy a couple of times in his life, at least in part because of his interest in Pythagoras. In his written dialogues, Plato developed Pythagorean as well as Socratic ideas. Plato also followed Pythagoras in forming a school, which became known as the Academy.

Work

Next to nothing is known of the way the Academy was run, but a great deal is known about Plato's writings, since all of his dialogues have survived. The dialogues present at least three different theoretical systems, probably from Plato's early, middle, and late periods, though any such dating is speculative and controversial. The early dialogues focus on ethical issues, and usually end with the speakers admitting their ignorance. For example, in the *Laches* the question is "What is courage?" in the *Euthyphro* "What is reverence?" in the *Charmides* "What is moderation?" in the *Lysis* "What is a friend?" and in the *Protagoras* "How are the virtues alike?" Though the arguments are inconclusive, they give an account of virtue as purely a matter of intellect, which is contrary to the widespread belief, then and now, that virtue requires proper desires or a good will in addition to technical know-how.

The middle and late dialogues end with the speakers reaching positive conclusions that are not limited to ethics. In the middle dialogues, such as the *Phaedo, Symposium, Phaedrus,* and *Republic,* Plato uses arguments to prove, as well as myths and metaphors to embellish, an account of the soul as having three parts: reason, which aims at truth; emotion, which seeks social values such as prestige; and desire, which aims at material satisfaction. This soul is immortal and destined to enjoy the beauty of divine objects that are not seen with the senses but understood, in much the way one understands mathematics with the intellect. It is the nature of these souls to be constantly reincarnated into various human and animal bodies. The process of reincarnation disorients the soul and makes it believe that sense objects are the only realities. Proper reflection on human crafts and sciences, as reflected in the use of language, enables human souls to recognize ultimate reality. The crucial turning point comes when one realizes that all well-made or beautiful or good objects share the same qualities or structure or *Form.* For example, it is not by sensory perception of particular beds that an expert carpenter or engineer designs and builds a bed, but by an intellectual recognition of what function beds are meant to perform. When the soul recognizes the reality of the Forms, and turns away from the senses towards such intellectual, math-like reasoning, it begins its path towards salvation. The soul achieves salvation by recognizing that the realm of Forms, not the material world, is true reality, so that one's desires for bodily and social goods cease to attach the soul to the material world, with the result that, at death, the soul is not drawn back into another body but ascends to the realm of the gods, if only for a limited time.

In the *Timaeus,* perhaps his most influential contribution to the dialogue between science and religion, Plato extends this account to general cosmology, explaining the design in the visible world by referring to a divine craftworker who fashioned the whole (by referring to Formal reality, of course) and insured its proper function by making it a living thing with a soul. Plato begins the tradition of *perfect-being theology,* which argues that God must be perfect, hence good, unchanging, eternal, and so on. In the later dialogues, beginning with the *Parmenides,* Plato raises problems with his theory of Forms, leading him not to abandon it but to abandon his middle period confidence that the Forms are simple enough that human minds can unmistakably know them without possibility of error.

Influence

Plato's influence on science and religion is probably greater than any other single person's. He lived at a time when there was no sharp distinction between the methods of religion and of science, and he was early enough in the history of western civilization to cast his shadow over the development of western science and religion. His influence on science is largely through Aristotle, who accepted with modifications Plato's view that the world can be explained in terms of form and matter and teleology, that is, the function objects are designed to perform. These categories dominated, and perhaps stifled, scientific thinking until the scientific revolution of the 1600s, when mathematical advances allowed scientists to try to explain the laws of nature in purely mechanistic terms (of particles pushing and pulling particles). Even in that revolution, Plato's influence continued. For instance, Galileo Galilei (1564–1642) used Plato's method of writing dialogues in the great debate between Ptolemaic and Copernican world systems to challenge the weight of religious authority by appeal to the light of reason.

Plato's influence on religion is even more profound. Philo (c. 20 B.C.E.–c. 50 C.E.) attempted to explain Jewish religion in Platonist terms and set a model that would be followed by Christians. In the three centuries after the death of Jesus, Christians had to choose between different interpretations of their faith as found in their sacred writings. As they worked to establish a biblical canon and creeds, they found themselves engaging in discussions shaped by Plato's and Aristotle's metaphysical and theological ideas. Some of these early writers, such as Tertullian (c. 160–c. 225), deplored any attempt to produce a platonic Christianity. Others, such as Origen (c. 185–c. 254), used platonic reasoning to defend the faith in a manner that would be followed by Augustine of Hippo (354–430), who in turn influenced all later Christian theology. Christian apologists appealed to platonic arguments to show that God exists and is perfectly good, that God designed the world, and that human beings have immortal souls. Then they supplemented these arguments with revelations from scripture. While critics of Christianity's Hellenization continue to this day, orthodox Christianity remains in the mold of perfect-being theology, and apologists continue to use platonic arguments.

See also ARISTOTLE; AUGUSTINE; CHRISTIANITY; GALILEO GALILEI; IDEALISM; JUDAISM; SOUL; TELEOLOGY

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PLAYING GOD

The phrase "playing God" is not a theological term; rather, it derives from secular culture and functions as a naturalistic proscription against scientific or technological interventions into nature. It functions as a warning that manipulation of natural processes may precipitate a disaster, one ironically triggered by human action but uncontrollable by human remedy. The commandment against playing God appears most frequently at the intersection where new developments in genetic research meet public policy.

The phrase "playing God" carries at least three overlapping meanings. The first refers to the sense of awe rising from new discoveries into the depths of life. Natural mysteries are being revealed, and scientists, who are the revealers, sense that humans are on the threshold of acquiring God-like powers, especially in matters of life and death.

The second meaning of "playing God" supposes that scientists are substituting themselves for God. Like Prometheus, scientists are said to be overstepping finite limits; out of pride or hubris they are risking a backlash from nature. This leads critics to prescribe a new commandment: Thou shalt not play God. This commandment relies on the Bible: "pride goes before destruction" (Prov. 16:18). "Playing God" means confusing knowledge with the wisdom one needs to decide how to use knowledge. In the battle between science and society, critics point to the deterioration of the ecosphere as an example of the consequences of unwise employment of science and technology.

In the field of genetics, the phrase "playing God" refers to the sacralization of DNA, manifest in moral injunctions against altering human DNA, especially altering the germline that could influence future generations. The sacralization of what evolution has created appears also in the opposition to genetically modified foods (GMFs), wherein what is natural is presumed to better for health than what is technologically modified.

Even though it is a secular phrase, the three meanings of "playing God" prompt theologians to ask questions about the relationship between the divine creator and the human creature. Unlike a naturalism that treats nature itself as sacred and inviolable, Christian, Jewish, and Muslim theists hold that God as creator and lover of all things is alone sacred. Natural life, important as it is, is not ultimate. The creator, not the creation, is sacred.

See also GENE THERAPY; GENETIC DETERMINISM; GENETIC ENGINEERING; GENETICS; HUMAN GENOME PROJECT

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TED PETERS

PLURALISM

The term *pluralism* is applied to philosophical positions emphasizing diversity and multiplicity over homogeneity and unity. The word first appeared in the work of Christian Wolff (1679–1754) and was later popularized by William James (1842–1910).

Ontological pluralism

Just as one can distinguish substantival monism (everything is explicable in terms of one thing) from attributive monism (everything is explicable in terms of one kind of thing), so can one discriminate *substantival pluralism* (everything is explicable in terms of a multiplicity of substances) from *attributive pluralism* (everything is explicable in terms of a multiplicity of kinds). Sometimes substantival pluralism is called *weak pluralism,* and attributive pluralism is called *strong pluralism*.

Opposing the monistic metaphysics of Parmenides' Eleatic School, ancient proponents of pluralism include Empedocles (495–435 B.C.E.), who held that everything is comprised of four elements (earth, air, fire, and water); Anaxagoras (500–428 B.C.E.), who asserted that all things are made of up of bits of every thing; and the atomists Leucippus (fl. 450–420 B.C.E.) and Democritus (460–370 B.C.E.), who asserted that all things are constituted by indivisible particles configured in different ways. Aristotle (384–322 B.C.E.) and Gottfried Wilhelm Leibniz (1646–1716 C.E.) can also be considered pluralists, the first because of his claim that reality is ultimately comprised of individual substances, the second because of his view that reality is made up of an infinite number of elemental monads having the fundamental attribute of perception.

Like substantival and attributive monism, substantival and attributive pluralism are logically independent. Because Baruch Spinoza (1632–1677) held that there is one substance with an infinity of attributes, he is a substantival monist and an attributive pluralist. Alternately, because Leibniz claimed that all monads have the same attributes, he is an attributive monist and a substantival pluralist.

In *A Pluralistic Universe* (1909), William James links pluralism and monism to the acceptance or rejection of the doctrine of internal relations. Accordingly, pluralism "means . . . that the sundry parts of reality *may be externally related*" (p. 274). While the pluralist believes that things are what they are apart from their relationship with other things, the monist claims that each thing is what it is only because of its relationship with other things—and ultimately with the whole containing them.

Cognitive pluralism

While the Western philosophical and theological tradition has generally sought fundamental unity in ontology, truth, and meaning, recent thinking has soundly criticized this project. Among the complex reasons for this is the contemporary rejection of the correspondence theory of truth. If one cannot justifiably speak of a determinate contour of the world apart from human awareness, conception, and language about that world, then it seems there can be no "mirroring" of the world in representation and language, no ultimate criteria by which to adjudicate conflicting interpretations of reality. Accordingly, all that remains are perspectival interpretations based upon discipline-specific assumptions about rationality and truth. Thus *cognitive pluralism* arises, a situation owing much of its popular development to the later Ludwig Wittgenstein, Thomas Kuhn, Paul Feyerabend, Richard Rorty, and the French postmodernists.

Jean-Francois Lyotard describes such a pluralism in his work, *The Postmodern Condition* (1984). Over and against modernity's universalizing reason and discourse, he points to the existence of various epistemic social practices and to the multiplicity of linguistic signifiers, discourse genres, and narratives. Because the assumptions underlying scientific activity are not self-evident, scientific discourse is controlled by various meta-prescriptive rules. Since such rules are locally assumed, there can be no universally applicable, rational discourse. Accordingly, postmodernism privileges antirealism over realism, perspectival epistemology over neutral epistemic and transcendental standpoints, pragmatic truth over the correspondence theory, and local narratives over overarching metanarratives. Cognitive pluralism rejects any foundationalist claim that knowledge is ultimately derivable from indubitable propositions or experiences; it recognizes a diversity of cognitive styles, patterns of rationality, and sensibilities, and it assumes that different sets of justified beliefs can exist alongside each other.

Other pluralisms

One can also identify *ethical pluralism, discourse pluralism,* and *explanatory pluralism*. Ethical pluralism claims that there are a number of incommensurable perspectives on the good or just society. (It can also mean the existence of a plurality of self-justifying, fundamental moral principles.) Discourse pluralism affirms the legitimacy of various kinds of discourse in speaking about a region of being. It holds that there can be irreducible levels of description, yet denies that each description refers to entities having metaphysical existence (e.g., possible worlds, numbers, mental states, etc.). Finally, explanatory pluralism asserts that explanations at different levels of description (e.g., psychology and neuroscience) can profitably be offered in the absence of reduction and without claiming the mutual metaphysical existence of the events and entities referred to in each (e.g., Cartesian dualism).

Pluralism, science, and theology

Is genuine dialogue between postmodern science and theology possible, or does the pluralism and localization of postmodern discourse produce epistemological incommensurability? Are there only isolated local narratives whose "truths" cannot be interrelated? Many in the theology-science discussion deny this radical claim. Wentzel van Huyssteen suggests that evolutionary epistemology reveals the biological roots of all rationality and thus provides a suitable basis for postfoundationalist rationality. Niels Gregersen attempts to fit cognitive pluralism into a common framework of rationality by using Nicholas Rescher's pragmatist coherence theory. Gregersen claims that coherence is the critical norm for all types of knowledge and that it provides a middle way between modernity's critical realism and the radical pluralism espoused by many postmodernists.

Explanatory pluralism is also important in the science-theology discussion. Accordingly, events within a common domain having both a physical and theological description can have both a physical and theological explanation. One can, however, question the coherence of explanatory pluralism, citing what Jaegwon Kim has called the "Principle of Explanatory Exclusion": There cannot be two complete and independent explanations of the same event.

Finally, one might ask if and how *ontological pluralism,* either in its substantival or attributive forms, is more conducive than monism for conceiving how God might act within the universe.

See also EXPLANATION; ONTOLOGY; POSTFOUNDATIONALISM; POSTMODERNISM; PRAGMATISM

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DENNIS BIELFELDT

PNEUMATOLOGY

Pneumatology refers to either the Christian doctrine of the nature and work of the Holy Spirit, or the study of human beliefs in spiritual beings. The term *pneumatology* also refers to the scientific study of air or gases. The Greek word *pneuma* suggests both wind and smell, as well as divine or human breath. Whereas notions of *pneuma* and spirit in ancient and medieval times referred to an earthly or bodily quality, since the sixteenth century the dichotomy of spirit and body emerged, modifying the conception of *pneuma* in time with the modern split of man and nature. The question of whether and how nature and human beings are empowered by spiritual energies and a divine spirit ought to be at the core of a dialogue between religion and sciences that claim to investigate nature in regard to invisible dialectics behind visible phenomena. The Judeo-Christian tradition offers a manifold of concepts for pneumatology, even if these have not yet been adequately tapped in a larger-scale dialogue with modern science.

See also HOLY SPIRIT

SIGURD BERGMANN

POSITIVISM, LOGICAL

The term *logical positivism* is particularly associated with the so-called Vienna Circle, a group of leading philosophers, mathematicians, and scientists that met in Vienna, Austria, in the late 1920s and early 1930s, with German philosopher Moritz Schlick (1882–1936) as chairman. They put forward what they regarded as a "scientific world-conception," which was both anticlerical and opposed to metaphysics. It was, they believed, characterized by two main features. The first was a general empiricism, and the second a devotion to a certain rigorous way of thinking that they called *logical analysis*. This relied particularly on the techniques of modern formal logic.

Empiricism, in the tradition of such philosophers as David Hume (1711–1776), holds that knowledge can only be obtained from direct experience. Although explicitly a science-based philosophy, it always causes problems for science because science always wishes to generalize from present experience through induction. A strict empiricism will, however, wish to deduce all claims to knowledge from the direct experience of which we are infallibly aware. Knowledge is the product of our pooled, intersubjective experience. What is beyond the reach of human perception and observation cannot be judged to be real. In its effects, the view becomes centered on human judgment and dependent on human capabilities. It is anthropocentric in that it will only deal with what exists in so far as it is accessible to human experience. The latter is defined in terms of what is "immediately given." In other words, what is in principle beyond the reach of the human senses cannot be meaningfully discussed. Science defines what it is possible to know, and a strict empiricism sets the limits, as the manifesto for the Vienna Circle puts it, "for the content of legitimate knowledge" (p. 309).

The Circle held that "the meaning of every statement of science must be statable by reduction to a statement about the given" (p. 309). This puts the whole of science (and hence, they believed, of knowledge) on a firm empirical footing. It is, however, worth noting that, even at the time, it was questionable whether this gave an adequate account of physics. Modern quantum mechanics has been plagued by disputes about the status of subatomic particles. These disputes often themselves stem from positivist views about the dependence of knowledge on sense experience. The difficulty is how far we can posit entities that by definition we cannot observe. Can they be thought really to exist even though they cannot be directly observed? That these kinds of questions were major stumbling blocks can be illustrated by considering that for logical positivists even the issue of the other side of the moon was a problem before humans had actually observed it. They could only say that it could be observed "in principle," and indeed it was eventually observed by humans. There are, however, many items to which modern physics wishes to refer that cannot be observed even in principle, unless those words are stretched beyond any recognizable use. What of the other side of the universe, or the interior of a black hole, not to mention quarks and other subatomic particles?

The influence of the Vienna Circle

The fame and influence of the Vienna Circle began to be felt in the 1930's. Such eminent figures as philosophers Rudolf Carnap (1891–1970), Herbert Feigl (1902–1988), and Friedrich Waismann (1896–1959), mathematician Kurt Gödel (1906–1978), and sociologist and economist Otto Neurath (1882–1945) were members, and their own individual influence was spread as they were all scattered across the globe as a result of the political upheavals of the 1930's in Central Europe, leading up to the Second World War. Other well-known figures were associated in some ways with the Circle. They tended to see Ludwig Wittgenstein (1889–1951) as one of their own, although, particularly in his later philosophy, he reacted very much against the idea that only science could set the standard for knowledge. Philosopher Karl Popper (1902–1993) also betrays some of the influence of the Circle, not least by arguing that the test for science was its ability to test empirically its theories by seeing if they could be falsified. This was a variation on the Circle's insistence of being able to test scientific theories through empirical verification. His argument was that conclusive verification was impossible to achieve. One can never know that all members of a class have been seen. For example, it is better policy to try to refute the theory that all swans are white than to seek to confirm it. A single black swan will be enough to falsify the theory. Popper's philosophy of science is therefore geared to making conjectures and attempting to refute them, rather than trying to confirm them. The result inevitably implies a certain agnosticism about scientific truth. Theories always have to be tested for possible falsehood. Yet we cannot know that they are true but only that they have so far survived scrutiny.

W. V. O. Quine. Two other philosophers attended the meetings of the Circle and were influenced by its outlook. W. V. O. Quine (1908–2000) was one of the leading American philosophers of the twentieth century and put forward a science-based philosophy. He was, however, also influenced by American pragmatism and criticised some of the Vienna Circle's basic tenets. In particular, it was held that all statements were either *synthetic* (subject to empirical checking and verification) or *analytic* (true by definition or by virtue of the meanings of the words used). An example of a synthetic statement would be, "All swans are white." One can discover there are black swans. Analytic statements would include, "All bachelors are unmarried" and "Two and two are four." One could not discover either statement to be false by looking at the world. Quine, however, challenged the whole analytic-synthetic distinction, and in so doing, undermined much of its empiricism. He also made space for theoretical entities, such as electrons, which might not be cashed out wholly in empirical terms. He did, however, continue in the belief, strongly held by the Circle, that philosophy was to be subordinated to science, and that there was no room for metaphysics, which could justify the practice of science in the first place.

A. J. Ayer. The other major philosopher who attended meetings of the Circle was A. J. Ayer (1910–1989). He became the voice of logical positivism in the English-speaking world through the publication of his influential *Language, Truth and Logic.* First published in 1936 as the first book of a young man, it argued that meaningful statements were to be divided into the two categories of the analytic and synthetic. Any other category of statement had to be dismissed as meaningless. He thus dismissed all metaphysics, and that explicitly included religious statements about God. Genuine statements of fact had to be empirically verifiable. Nothing could be factually significant to people unless they knew how to verify the proposition it purports to express. This was the *criterion of verifiablity* or the *verification principle.*

Since the existence of God is not a mere tautology (true by definition), according to Ayer, it could only be a factual statement with empirical consequences. His argument can be illustrated by the way he deals with the suggestion that the occurrence of regularities in nature could be evidence for the existence of God. Yet, according to Ayer, if the claim that there is a god amounts empirically to no more than the claim that certain types of phenomena occur in certain sequences, then talking of God is equivalent to talking of those regularities. Ayer could not allow reference to anything beyond our experience. Speaking of the transcendent, like the metaphysical, was just so much hot air, not a genuine assertion of anything. A parallel might be the claim that there is a *heffalump* in the garden. If a person said there was a heffalump, but did not know what a heffalump looked like, or indeed how to ever recognise a heffalump, it becomes difficult to know what one is saying. Talking of something that is in principle unverifiable becomes perilously like not saying anything at all.

What went for religion also applied to other wide categories of apparent statements, such as those of ethics and aesthetics. They are not scientifically verifiable and therefore cannot be regarded as saying anything that could be true or false. It has already been remarked that even contemporary physics may want to refer to what lies beyond possible human observation, so the verification principle is a blunt instrument even in science. It was commonly seen, though, to get into most trouble when people questioned the status of the verification principle itself. If one states that the only meaningful statements are those that can be empirically verified, or that all metaphysical claims are literally nonsense, how can one empirically verify those assertions? Is not the basic claim itself meaningless because it is beyond the scope of empirical observation? Ayer's later claim was that the verifiability criterion was "an axiom," but particular axioms do not have to be chosen. If someone sees that the adoption of such a rule, or starting point, involved the jettisoning of much that is deemed important in human life, that might seem a good reason for not having the axiom in the first place.

Positivism and the status of science

Despite its shortcomings, Ayer's verification principle, and the veneration for science expressed by the repudiation of metaphysics, had a profound affect on theology and the philosophy of religion for many years in the middle of the twentieth century. In many ways, logical positivism still casts its shadow. The idea that religion is not entitled to talk of realities beyond human experience is a seductive one. Yet it strikes at the root of any belief that the physical world is not all that there is, but that there is another nonmaterial realm. Even within theology, there is a constant temptation to reduce talk of a nonmaterial, transcendent realm, such as the Kingdom of Heaven, to matters of everyday experience. It is still often thought that what cannot ultimately be cashed out in empirical terms cannot refer to anything real. This involves changing our concentration from, say, the reality of God, to issues concerning human reactions, attitudes, and practices. Yet in the end, this is an old-fashioned materialism in a sophisticated guise. It is no different from Thomas Hobbes (1588–1679), the seventeenth-century philosopher, saying that there is no difference between God speaking to someone in a dream and dreaming that God spoke.

In the debate about the relations between science and religion, the legacy of logical positivism is to accord science a philosophical status that is denied metaphysics in general and theology in particular. The tendency will be to assume that the assertions of science have an epistemological priority that theology must always respect. In any dispute science must always be given priority. Yet, logical positivism was an anthropocentric view. It related everything to actual and possible sense experience, which had to be human sense experience. We could not understand claims of radically different kinds of experience. By definition, therefore, it was related to human understanding, and the possibilities of human knowledge. This, though, is different from issues concerning the nature of reality. Science is always human science, but it purports to be about a reality that goes beyond, or transcends, our limited and provisional understanding. Philosophy, and metaphysics in particular, has to recognise these limitations. We have to accept that what exists and how we can know it, are radically different kinds of question. This is the difference between ontology and epistemology. The mistake of the Vienna Circle and those it has influenced is to reduce references to what exists to talk of how we can find it out, when who "we" are is not always clearly defined. Any exaggerated respect for science never makes it clear whether it is upholding present science, or science as it one day could be. Yet the latter idea itself begins to seem highly metaphysical in the sense that it outstrips any possible method of verification at present available to us.

Logical positivism represents the extreme version of the respect for science that permeates contemporary thinking. Yet the status of science is itself an issue of major philosophical concern that cannot be taken for granted. Not least is the fact that science has to assume the existence of an ordered and regular world. This is a resupposition of science. We may as a matter of fact experience nature as uniform, but why is this? Why do humans have the ability, through reason, to understand the innermost workings of the physical world? Why is mathematics somehow applicable to the workings of nature? For logical positivism, questions like these were insoluble, and therefore meaningless in the first place. Yet the worst way of dealing with awkward questions is to pretend that they do not exist on the grounds that they are meaningless.

See also CRITICAL REALISM; EMPIRICISM; PHILOSOPHY OF SCIENCE

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ROGER TRIGG

POSTFOUNDATIONALISM

One of the central methodological issues in the dialogue between theology and science is the nature of rationality. The way one imagines the operation of reason within and between these disciplines will shape the way one works to bring them into dialogue. The postfoundationalist model of rationality has emerged out of this ongoing discussion as an explicit attempt to move beyond the impasse between foundationalist and nonfoundationalist models. Unlike the foundationalist, the postfoundationalist acknowledges that rational reflection (and more broadly, experience itself) is always and already conditioned by communal and historical contexts. Unlike the nonfoundationalist, the postfoundationalist does not believe that this contextuality makes it impossible to reach beyond the confines of particular communities or to strive for interdisciplinary and transcommunal conversation. The *post* is not merely *after,* nor simply *against* foundationalism (as in nonfoundationalism), although it is both of these. Postfoundationalism is the search for a middle way between the objectivism of foundationalism and the relativism of many forms of nonfoundationalism.

The philosophical theologian most closely associated with this view is J. Wentzel van Huyssteen. His book *Essays in Postfoundationalist Theology* (1997) outlines the contours of this model of rationality, and he fills out the details in *The Shaping of Rationality: Toward Interdisciplinarity in Theology and Science* (1999). Philip Clayton also illustrates this model of rationality in several of his works, including *The Problem of God in Modern Thought* (2000). In his earlier methodological contribution to the dialogue, *Explanation from Physics to Theology* (1989), Clayton argued that rejecting foundationalism does not mean that one automatically falls into the waiting arms of the nonfoundationalists. Several other scholars share the family resemblance of postfoundationalism (for examples, see F. LeRon Shults *The Postfoundationalist Task of Theology,* 1999). Both van Huyssteen and Clayton suggest that the entire debate between foundationalism and nonfoundationalism is based on an outdated epistemological dilemma. Several dichotomies are at play here, but they are all embedded in a deeper assumption that separates epistemology from hermeneutics.

Epistemology and hermeneutics

In the search for apodictic knowledge (*episteme*), classical foundationalists privileged epistemology as the primary enterprise of philosophy, and eschewed the subjective factors that lead to mere opinion (*doxa*). Nonfoundationalists valorize the play of hermeneutics as philosophy's task; since all we have is opinionated interpretation, the ancient (and "modern") goal of objective knowledge must be given up. Postfoundationalism aims to accommodate the postmodern critique of neutral *episteme* without collapsing into relativist hermeneutics. Conversely, it affirms the modernist interest in general patterns of rationality, but rejects foundationalist absolutism. Postfoundationalism insists on a constitutive reciprocal relation between epistemology and hermeneutics, avoiding a collapse into the former (with its "meta-narrative") or the latter (with its isolated narratives). The goal is to maintain the search for truth as an ideal that drives inquiry, without asserting that any particular claim to knowledge provides a totalizing and final metanarrative. For van Huyssteen the search for "intelligibility" is upheld as a common link between theology, philosophy, and the sciences. Accepting the ideal of intersubjective intelligibility, however, does not entail objectivism. An awareness of the "fallibility" of all human knowledge, argues van Huyssteen, protects against the absolutism and hegemony that worry the nonfoundationalist. Further, to avoid fideism, which sometimes haunts nonfoundationalist appeals to the faith of a particular community, the postfoundationalist holds onto the ideals of truth, objectivity, and rationality, while at the same time acknowledging the provisional, contextual, and fallible nature of human reason.

Experience and belief

As a theory of belief-justification, foundationalism distinguishes between "basic" beliefs, which are justified without reference to other beliefs, and "nonbasic" beliefs, which are justified by their inferential relation to basic beliefs. In this view, basic beliefs emerge out of and are immediately justified by experience (whether rational or empirical); inferential justification then flows in one direction—from basic to nonbasic beliefs. One can imagine a "pyramid" of knowledge secured by its firm foundation. Nonfoundationalists typically hold to a form of coherentism, which is the main competitor of foundationalism vis-à-vis the debate over the justification of belief. The favorite images here are a "web" of interconnected beliefs or a "raft" that must be repaired while afloat. Foundationalism has difficulty defending its criteria for the basicality of a belief and accounting for the interdependence of all human beliefs; nonfoundationalism, insofar as it maintains strict adherence to coherent relations among beliefs as the only criterion of justification, has difficulty indicating the truth of its beliefs outside the system. If these are the only options, then philosophers of science and theologians must choose between the alleged security of the foundationalist pyramid and the turbulence of the coherentist raft.

In *The Shaping of Rationality,* van Huyssteen suggests a balance that affirms the broader networks of belief in which rationally compelling experiences are already embedded and recognizes the way in which beliefs are anchored in interpreted experience. Against the foundationalist idea that some beliefs enter the web neutrally (without being interpreted), van Huyssteen insists that all experience is interpreted. Rather than leading to nonfoundationalist relativism, however, he argues that one can critically explore the experiential roots of beliefs without feeling compelled to throw out one's commitment to the explanatory power of those beliefs. In her *Evidence and Inquiry* (1993) Susan Haack asserts that foundationalism and coherentism do not exhaust the options. Against coherentism, foundationalism requires that justification occurs in one direction; against foundationalism, coherentism insists that justification is exclusively accomplished in terms of the relations among beliefs. Haack argues for a middle way that she calls *foundherentism*—the justification of beliefs is not unidirectional *and* a coherent relation among beliefs is not sufficient for their justification.

Individual and community

The debate over belief-justification is closely linked to the question about the way in which individual and communal factors shape the formation of beliefs. The Enlightenment ideal was the "man of reason" who stands alone and objectively measures the world. All rational individuals can and ought to come to the same conclusion, irrespective of their subjective interests or communal background. Nonfoundationalists build upon the historicist critique of this model of rationality, and emphasize the contextual factors that influence an individual's acceptance of criteria for what is reasonable. Pointing out the linguistic and communal mediation of an individual's web of beliefs, nonfoundationalists argue not only that the modernist ideal is impossible but also that it is undesirable because it so easily leads to the domination of one narrative rationality over another. In its extreme relativist forms, this leads to the conclusion that local theologies and local sciences have their own incommensurable rationalities and are not accountable to other communities of inquiry.

The postfoundationalist agrees that we must move beyond foundationalist theories of rationality that aim for universality and certainty, but finds the nonfoundationalist price for the immunization of theological rationality from critique from other sciences too much to pay. Postfoundationalism accepts the nonfoundationalist sensitivity to the hermeneutical conditioning effected by being situated in a community of inquirers, but refuses to give up the intuition that it is the individual who actually makes rational judgments. This model of rationality recognizes that an individual is always a participant within a particular community of inquiry and so works out of the standards of its tradition, but also acknowledges that the personal voice of a rational agent may also critique those standards through distanciation from the tradition.

Explanation and understanding

The dialogue between science and theology has been shaped by the separation in western culture between the natural and the human sciences. This modern dichotomy was made explicit by Wilhelm Dilthey in the nineteenth century, but was grounded in the metaphysical dualisms of early modern thought (extended vs. thinking substance, nature vs. mind). On this model, the natural scientist objectively observes and measures the material world, offering an *explanation* of the facts in terms of universal laws. The human (or social) scientist examines the behavior of human beings over time, presenting an *understanding* of the value of a particular event in the pattern of a broader context. With these as the available options, some theologians tried to model the study of the Christian religion after the natural sciences; this typically took a foundationalist form in which basic data is posited (e.g., in Scripture or religious experience) and propositions are objectively inferred. Nonfoundationalists, on the other hand, are often satisfied with categorizing theology as a "human" science, involving the depth description of particular linguistic communities.

For the postfoundationalist, all human knowing and so all of the sciences are characterized by both hermeneutical understanding and the drive toward experientially adequate and intersubjective explanation. In *Explanation from Physics to Theology* Philip Clayton proposes a mediating position that recognizes the shaping influence of contexts of meaning, but simultaneously allows for general standards or criteria for explanation in the sciences. He defines *understanding* broadly as an intuitive grasping of patterns of meaning, and *explanation* as a rational reconstruction of these interrelated structures in a primarily theoretical context. Although the values, interests and goals that guide their operation will differ, explanation and understanding are interdependent and operative in both theology and science. By exploring the dynamics of rationality that lay across these fields, postfoundationalism aims to contribute to a safe interdisciplinary space for the dialogue between science and theology.

See also COHERENTISM; FALLIBILISM; FOUNDATIONALISM; NONFOUNDATIONALISM; POSTMODERNISM

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F. LERON SHULTS

POSTMODERNISM

Postmodernism is an abstract, theoretical term and should be distinguished from *postmodernity,* which describes a sociological or cultural climate. The term *postmodernism* was coined in the late 1940s by British historian Arnold Toynbee, but used in the mid-1970s by the American art critic and theorist Charles Jencks to describe contemporary antimodernist movements like Pop art, Concept Art, and Postminimalism. Jean-François Lyotard, in his book *The Postmodern Condition: A Report on Knowledge* (1979), was one of the first thinkers to write extensively about postmodernism as a wider cultural phenomenon. He viewed it as coming both before and after modernism, the reverse side of it. As such, postmodern moments have subsequently been discerned in thinkers as various as the eighteenth-century Scottish philosopher David Hume, the nineteenth-century Danish philosopher, Søren Kierkegaard, and the German philosopher Friedrich Nietzsche.

Characteristics of the postmodern

For Lyotard, the postmodern is characterized by an incredulity towards metanarratives. By *metanarratives* he means the appeal to explanatory principles that presume to tell the story of the ways things are. Metanarrratives are accounts of the origin, foundations, and formations of the various forms of human knowledge: for example, motion (Isaac Newton), the mind (René Descartes and Immanuel Kant), history (George Wilhelm Friedrich Hegel), the economy (Karl Marx), psychology (Sigmund Freud), and society (Emile Durkheim). Metanarratives assume the world and human activity within it can be known as a whole because it is rational and organized according to certain universal and verifiable laws or principles. Postmodernism announces a radical scepticism towards such universalism and the objectivity or view from no where that is presupposed in investigations into and accounts of these foundational laws or principles. Postmodernity, then, would describe a cultural situation in which such scepticism was culturally dominant. In such a time, the postmodern would not just be a theoretical critique of modernity's rational understanding of the world and the universalism of that reasoning. The postmodern would be an attempt to rethink and experience the world according to that antifoundationalism and the turn towards local knowledges or views from a specific standpoints: gendered knowledges, ethnic knowledges, religious knowledges, for example.

The postmodern world is composed of little other than grand narratives, accounts of knowledge that are aware they are partial in nature, refracted through a certain cultural perspective and constructed. Their constructedness is important, specifically when attempting to assess the impact of postmodernism on religion, science, and the debates between them. The constructedness of knowledge challenges the foundational realism of the empirical sciences in which language is simply viewed as transparently communicating the world as it is, mediating between mind and matter. When knowledge of "what is" is understood as constructed, then reality is soft, pliable, and ultimately open to endless interpretation and reinterpretation. Language no longer simply mediates or acts like a clear window on the world. Language creates, fashions what people see and what they understand by what they see. The universal concepts governing thinking in both the human and natural sciences in modernity—truth, nature, reality, history—are viewed as unstable. The instrumental thinking that accumulated "neutral" data, measured it, calculated the options, and arrived at general statements through an inductive reasoning is seen, at best, as just one form of rationality. Explanation becomes a mode of interpretation. Time (as a sequence of present moments), space (as that which either contains or is the extension of things), matter (as composed of atomized particles) all are refigured by the nonrealism and antifoundationalism of the postmodern. Attention to the constructed nature of representing the world leads to an emphasis upon the metaphoric, the symbolic, the allegorical, the theatrical, and the rhetorical. Rather than a world of inert entities, passive before objective enquiry, in the postmodern all things signify, entities are expressive. The real is an aesthetic effect so that belief in the literal is exactly that, *a belief*. The literal, the transparency of modernity's understanding of the meaning *behind* language, becomes an ideology.

Postmodern science and religion

While Silicon Valley scientists were establishing both themselves and cyberspace, the postmodern condition was producing its own understanding of virtual reality. And while astrophysicists were exploring the collapse of stars and the creation of black holes, the postmodern condition was producing its own understanding of the implosion of secular modernity and the sacredness of the void. The parallelisms between what the empirical sciences term "discoveries" and the cultural sciences in postmodernity would call "inventions" are not felicitous but inevitable. If knowledge is produced rather than found within a particular cultural milieu, then such parallelism will necessarily occur. Mary Hesse had already demonstrated this in her book *Revolution and Reconstructions in the Philosophy of Science* (1980). Paul Feyerabend had taken cultural pluralism right into the heart of the empirical sciences with his *Against Method* (1975).

At the same time, the French philosopher and historian Michel Foucault was developing his genealogies and "archaeologies" of clinics, economics, madness, punishment, and sexuality, and extending the thesis that the way the world is understood and organized is governed by discursive acts of power and practical disciplines in which the body becomes the prisoner of the soul (or the way mind conceives the world to be). A sociology of knowledge led to a sociology of scientific knowledge. New histories were written that countered modernity's "progress" model of scientific discovery. New epistemologies and methodologies were sought, like the feminist standpoint work of Sandra Harding and Helen Longino, which examined *abduction*—or the choices made in scientific research prior to and governing inductive reasoning.

At the same time, a new marriage was emerging between the mythological and the technological. In modernity, as the sociologist Max Weber's "disenchantment thesis" taught, the job of science was to demystify the world, and the various technological revolutions were the practical outworking of this rigorous demythologizing. The success of science was measured by progress in terms of human control over the world. Everything could be explained; science would provide the answers, and technology would harness the answers in order to liberate human beings from the drudgery of labor for the pursuit of civilized living. The supernatural was for the superstitious and the ignorant; religion was for those needing private consolation. Stripped of its liturgies, stories, and priestcraft, religion expressed human ideals of the good life. The priest at the altar was replaced by the scientist in the laboratory as religion, among the enlightened, was viewed as mythological clothing for human aspirations, fears, and projections. As such, modernity's dreams were often secularized religious ones: a new Jerusalem of technological efficiency as intellectually hygienic as it was biologically controlled. The "disenchantment" of the world, cultivated by technological progress, was a fundamental tool in the secularization of the sacred. All values were to be found in this world, not beyond it, and human beings were capable of realizing the very highest of these values themselves, through rationalization and forward planning.

The emergence of the postmodern condition, in critiquing the grand narratives of explanation and pointing up the ideologies of control, appealed to what lay outside of the secular world-view. From the mid-1970s there has been revival of romantic thinking. The gothic imagination flourishes again in popular culture, not only in terms of vampires, warlocks, angels, dungeons, dragons, and fascination with the psychotic, but in terms also of a renewed interest in all things medieval. The mythopoetic was revived, and the character of that revival can be estimated by comparing the Narnia Chronicles of C. S. Lewis to Philip Pullman's *Dark Materials* trilogy or J. K. Rowling's Harry Potter series. For Lewis, Narnia was a separate realm reached only through the wardrobe in a professor's rambling Oxfordshire home. But in *Dark Materials,* the supernatural world is not distinct from the natural world, there is neither one nor the other.

Popular science (promoted in part by various governments wanting to interest the young in the technological and nurture a new generation of scientists and technicians) and science fiction assist now in the re-enchantment of the world. With the spread of home computers, the developments in telecommunications, digital graphics, and cinematic special effects, science promotes the bending of modernity's understanding of the real. Virtual reality is now not standing alongside some naturalistic prototype, virtual realities (plural) confuse any boundary between the natural and the supernatural. Science now promotes the transcendence of the human.

Two important thinkers have helped us to understand this postmodern science: Bruno Latour and Michel Serres. Latour's best known book, *We Have Never Been Modern* (1993), points out how modernity aspired to a transparency that separated one thing clearly from another. Modernity was committed to distillation. What it feared and policed was *hybridities*. As such, modernity produced and fostered a series of dualisms: the objective and the subjective; the body and the mind; the public and the private; the organic and the mechanical; the natural and the cultural. But the production and fostering of such dualisms required mediating agencies. The postmodern world is witnessing the return of the hybrid, as the mediating agencies can no longer cope with the infiltration of one category into another. The vampire, the cyborg, and the angel all figure this transcendence of the human, the instrumental, the calculated, and the rational in contemporary culture. The priest and the scientist are, as they often were in the mediaeval world, the same person.

Michel Serres book *Angels: A Modern Myth* (1993) expounds this new world-view in which postmodern science and religion fuse. Sketching a profound interrelatedness of all things, Serres denies material things are inert. All things communicate—the waves of the sea, weather systems, rock formations, human beings. The world is caught up in endless relays and interchanges of messages. As angels have traditionally been conceived as the purest of messengers, so the world can be viewed as participating in an angelic intercommunication that transcends this particular person or that particular object. Global telecommunications become an expression and development of this participation in a complex, discursive interconnectedness which, ultimately, for Serres, sings a doxology to the Most High. Serres practices the hybridity Latour informs us is the state of things, relating it specifically to a theological (in fact specifically Christian and sacramental) worldview.

Conclusion

The postmodern condition announces the collapse of secularism, but it also announces a new dialogue between religion and science. In premodernity, scientific enquiry submitted itself to religious judgement. In modernity, religion was deemed outdated, if not pathological, by the rise of the new sciences. In postmodernity, neither the oppositions nor the hierarchies pertain. And so the character of the debates between religion and science will change also. The earlier debates concerned themselves with attempting to show that there was no incompatibility between scientific discoveries and the religious perspective. They were conducted frequently by scientists with religious commitments, in an attempt to integrate two divergent views of the world. They constituted a form of liberal apologetics in which science offered the vision of what was, and religionists showed how that did not conflict with a theological worldview. The metaphysics of empiricism and positivism remained firmly in place, dictating the terms of the struggle and the attempts at *détente*. Postmodernism, having challenged those empiricisms and positivisms, having announced a contemporary incredulity in such foundationalism, will usher in a round of new debates between religion and science that will demonstrate a shift in cultural power, a reciprocal learning, a new respect. Serres's work shows the way, but religionists have recently appealed also to the work of the Oxford mathematician Roger Penrose who, in a different way, endorses an indeterminacy between the brain and the world such that both the material and the immaterial are caught up in complex informational processes. The various alliances between new age religions and concerns with ecology are also significant indicators of cultural change. The basis for the new discussions is an emphasis upon interconnectedness and attention to participating within open-ended informational systems in which the psychic and the material are not distinct but inseparable, mutually informing dimensions.

See also NONFOUNDATIONALISM; POSTFOUNDATIONALISM; POSTMODERN SCIENCE

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GRAHAM WARD

POSTMODERN SCIENCE

Postmodern science challenges the modern ideal of the neutral scientist who applies formal rules of deduction to develop theories that objectively explain empirical data. Alongside feminist (and other) critiques of metanarratives, it emphasizes the local contextual factors (i.e., language, culture, gender) that shape the theory-formation and practices of scientists. Modern (and especially positivist) science was characterized by a strong distinction between the objective (hard) sciences and the subjective (soft) sciences. Insofar as postmodern science blurs these boundaries and recognizes the overlap between explanation and understanding in divergent forms of human rationality, it helps to foster the dialogue between science and religion.

See also POSTMODERNISM

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F. LERON SHULTS

PRAGMATISM

Is pragmatism the optimistic expression of the industrial era, deemed to be vanishing in the postindustrial society, or is it a serious philosophical alternative to traditional rationalism and empiricism, idealism and realism? What is labeled *pragmatism* ranges from the philosophy of nineteenth-century American scholar Charles Sanders Peirce (1839–1914), who claimed inquiry for truth's sake, to Richard Rorty's (b. 1931) twentieth-century neopragmatism, which claims, in an antirealist spirit, that criteria of evidence are not objective but only conversational constraints. Most pragmatists, however, try to find a middle way between metaphysical realism and relativism, between dogmatism and skepticism, by using the pragmatic maxim. This maxim holds that in order to ascertain the meaning of an idea one should consider the practical consequences that might conceivably result from it.

Belief is considered to be guiding people's actions in that it is a habit, a disposition to behave. Its opposite is doubt, which, unlike René Descartes's methodological doubt, is involuntary and unpleasant, usually caused by some surprising phenomenon that is inconsistent with one's previously accepted beliefs. Inquiry starts when humans, like other organisms, strive to obtain an equilibrium with their environment, the inquiry manifesting itself in new habits and revised beliefs. Successful inquiry results in a stable viewpoint, but only temporarily stable, seen in the long run. Sophisticated inquirers will therefore always be motivated to further inquiry, transforming the primitive homeostatic process into scientific inquiry.

Universalizing pragmatism: John Dewey

American philosopher John Dewey (1859–1952) was deeply influenced by Peirce's idea of scientific method and inquiry, but Dewey broadens it to take on universal scope. He conceives of the scientific method simply as the way people actually think, or ought to think. Unlike Peirce, Dewey also emphasizes the immediacy of experience, generally characterized in terms of its aesthetic quality, as felt immediacy and, as such, basic and irreducible. Cognitive experience is the result of inquiry. The process starts when a person encounters some difficulty, proceeds through the stage of conceptual elaboration of possible resolutions, and results in a final reconstruction of the experience into a new unified whole. With this idea, Dewey and other pragmatists question what are labeled "spectator theories of knowledge," according to which knowledge is a kind of passive recording of antecedent facts. Instead, knowing is seen as a constructive conceptual activity, anticipating and guiding our adjustment to future experiential interactions with our environment. The classical ontological distinctions in philosophy between mind and body, between means and end, and especially between fact and value, therefore cannot be ascribed an absolute status but should rather be functionally and contextually understood. Consequently, Dewey rejects the idea of truth as correspondence of thought to unknowable things-in-themselves. Instead, it is a matter of successful adjustment of ideas to problematic situations. For that reason, Dewey prefers to talk about warranted assertability.

Pragmatism in science: W. V. O. Quine

Like all pragmatists, the neo-pragmatist W. V. O. Quine (1908–2000), one of the leading American philosophers of the twentieth century, also rejects the idea of reaching the balance between language, truth, and reality once and for all as an unusable fiction. He develops the idea of the interactivity between conceptual invention and discovery of content in the sense that the conceptual system as a whole has to pass the test against experience. There is no guarantee that any kind of truth could be excepted from a future process of revision. Since there is no unique method of finding truth, nor any universal language for finding the final conceptualization of the world, there is no way of talking about reality as such. Nevertheless, for Quine, the danger of relativism is illusionary. What has been obtained in scientific research through epistemological and ontological decisions is absolutely binding, although in the future it will probably have to be modified or even given up. In what way there will be a change, however, lies beyond present cognitive abilities.

Pragmatism in religion: William James

The objection of subjectivism and relativism is also directed against nineteenth-century American philosopher William James's (1842–1910) conception of truth. Unlike Peirce (and to some extent Dewey), James does not focus only on the empirically testable consequences of a belief. He rather shifts the emphasis to what the consequences of a person having a belief are. True beliefs work. Not surprisingly, this conception of truth has been taken as a straight identification of truth with utility. James, however, distinguishes between the different ways that different beliefs work. Concerning empirical judgments, "true" means "verified through observation and experiment." Thus, the accusation of identifying truth with utility cannot be applied to empirical judgments. Neither does it affect a priori truths since they are truths that one is prepared to accept in the sense of conceptual presuppositions by means of which one talks about reality. Only concerning a third kind of truths—moral, aesthetic, and religious ones—is the pragmatic identification of truth and usefulness valid. The kind of judgment involved here cannot be empirically verified. The truth-value of such judgments is given by their practical working in life. If religions shall be more than idle talk, they have to have practical consequences for the people who choose them; they have to work psychologically satisfactorily in their lives. James defends people's right to have religious beliefs if the choice between believing them and disbelieving them is unavoidable, and if they offer a real option, even though religious beliefs cannot be decided on the basis of empirical evidence.

Pragmatism in science and religion

In one specific sense there is, according to pragmatism, no difference between science and religion. Both activities have to be understood in relation to the kind of beings human are. Neither science nor religion can address reality as independent of human experience. However, whereas science deals with experimental, observational experience, religion concerns existential experience. A theory is empirically adequate if it enables people to generate testable hypotheses and thereby maintain what is true in the observable world. Religions and their secular counterparts are existentially adequate if they provide people with conceptions of life at its best so that, in the tension between how life is and how it could be, they can attain a feeling for good and evil, right and wrong, and thus generate values and meaning, and express what is true in their lives.

See also CONSTRUCTIVISM; CONTEXTUALISM; IDEALISM; REALISM

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EBERHARD HERRMANN

PRAYER AND MEDITATION

Prayer is the practice of communion with God and traditionally involves components such as confession, thanksgiving, and intercession (praying for the needs of others). Meditation is a form of spiritual practice based on focused attention that is restrained in its use of words or images. Whereas prayer is conceptualized in terms of a relationship with God, meditation does not necessarily make theistic assumptions. Prayer and meditation raise several issues for the science-religion discussion, including the effects of intercessory prayer for those prayed for and the more general benefits of prayer and meditation for those who practice them. There are both outcome questions about the extent of the benefits, and process questions about how benefits are mediated.

Intercessory prayer

The efficacy of intercessory prayer is not easy to investigate scientifically. To do so would obviously require a control group of people who are not prayed for. It would also be necessary to ensure that those being prayed for do not know that they are being prayed for; otherwise any benefits might be considered a kind of placebo effect. Indeed, it is often considered desirable during such a study that the people who pray do not know the full identities of those for whom they are praying. In a hospital setting, the medical staff also should not know the identifies of those being prayed for to ensure that they do not influence clinical outcomes by treating the prayed-for people differently.

Meeting all these methodological requirements involves creating highly artificial conditions. For example, it is questionable whether it is possible to pray effectively for people whose identities have been concealed. Even if such prayer is possible, it may be less powerful than heartfelt prayer for a known person. It is also arguable that knowing that the prayer is being undertaken for the sake of a scientific experiment undermines its effectiveness; perhaps prayer ought only to be undertaken out of concern for the person prayed for. There is also the theological question of how God might respond to testing the effectiveness of prayer scientifically. Prayer is primarily a matter of a person's relationship with God, not of control of the world.

Despite these problems, a number of scientific investigations of the efficacy of prayer have, in fact, been undertaken. The results are mixed and inconclusive, with some studies finding an effect, others not. However, there is certainly more evidence for the effectiveness of prayer than would be expected by chance. In the 1980s, Randolph Byrd carried out a study of nearly four hundred coronary care patients. A control group was prayed for, while an experimental group was not; other patients and medical staff were kept blind about who was in which group. When this experiment was concluded, the patients who had been prayed for had a better outcome. A number of well-designed studies have been conducted since then and have found significant effects from intercessory prayer, though some experts remain unconvinced by these studies.

Is there a way of explaining the efficacy of prayer that is consistent with the scientific worldview? In general, explanations are divided between those who invoke God and those who do not. Those who do not invoke God see the efficacy of intercessory prayer as a form of psychokinesis or remote mental influence. Those who invoke God see it as a special case of divine action.

A series of well-designed experiments have been conducted on "bio-psychokinesis" that indicate that it is possible to influence a range of specific biological functions in others without any immediate contact. Several of these effects have been well-replicated. It is possible that intercessory prayer, such as prayer for physical healing, is a specific example of bio-psychokinesis. Of course, that does not completely explain the phenomenon because researchers do not understand how bio-psychokinesis itself works. It may be preferable to look first for some not-yet-understood naturalistic explanation of bio-psychokinesis, rather than assume that a wholly non-naturalistic explanation is required.

Alternatively, the effect of prayer can be seen as a special case of divine action, but one in which divine action is triggered or facilitated by prayer. This raises the theological conundrum of why God should act in response to prayer rather than acting on God's own initiative. It is theologically objectionable to suppose that God is unaware of human needs or not motivated to respond unless prayer occurs. It is also objectionable to suppose that God is powerless to act without human prayer, though it is perfectly acceptable to suggest that, out of voluntary self-restraint, God might prefer to act in conjunction with the prayerful initiatives of human beings. If so, prayer could be seen as establishing a union of wills between human beings and God. Science provides a source of analogies for how that could come about. For example, it may be analogous to a nuclear resonance, or some kind of attunement.

A divine action model would probably predict that the prayer of people who have strong faith and lead good lives would be the most effective. A psychokinesis model of prayer would probably predict that prayer would be most powerful if carried out by people with psychic powers (which would, of course, have to be assessed in some independent way, to avoid circularity). There is thus some prospect of testing the different predictions of the two kinds of theories empirically.

Benefits to the person who prays

Next, there is the question of whether prayer benefits the person who prays. Here we are concerned not just with intercessory prayer but with the full range of prayer, including thanksgiving, adoration, confession, and petition. It is almost certain that prayer makes a valuable contribution to personal coping. However, actual evidence for this is not easy to collect. It would be hard to conduct a controlled study in which an experimental group prayed regularly over a sustained period, and a control group never prayed. Most people would not be willing to allow whether or not they prayed to be dictated by the requirements of an experimental design, certainly not for long enough to show a broad range of effects.

That means that the evidence will only be correlational in nature. There is indeed a good range of studies showing that people who pray tend to be better adjusted. One of the most sophisticated of such studies is that of G. Parker and L. B. Brown (1982), who found that prayer was one of the coping strategies that apparently helped to protect against depression. However, the problem with all such studies is that they are correlational, which interferes with firm conclusions about causal effects, particularly when so little is known about the causation of the phenomenon under investigation. There is also the problem that prayer is closely related to other aspects of religion, such as religious beliefs, experience, and public rituals. It is hard to be sure that it is prayer that helps, rather than those other aspects of religion.

It is nevertheless highly plausible that prayer is helpful, and it is not difficult to suggest how it might be so. It seems to serve as a cognitive method of coping with stress in which events are conceptualized in a broad framework of meaning. The religious frame of reference does not look at events primarily in terms of whether they are enjoyable, but in terms of how they relate to the purposes of God. It is a basic belief of many faith traditions that God can bring blessing out of adversity, and prayer facilities the application of that belief to particular events.

Attributional processes are important in coping generally, and the beneficial aspects of prayer are probably mediated in part by the attributional aspects of prayer. Prayer invites attributions to God, whereas otherwise there may be little alternative to attributions to one's own strengths or weaknesses, or to seeing events as the result of mere chance processes. Thanksgiving is an aspect of prayer that plays a particularly important role in the reformulation of attributions.

Meditation

Meditation has been widely studied scientifically, especially transcendental meditation. There is clear evidence that transcendental meditation produces a distinctive arousal pattern of relaxed alertness, and there is evidence also of its therapeutic value, not only on subjective measures such as anxiety, but on more objective measures such as use of drugs and alcohol. However, none of that may have much to do with religion; it may be that transcendental meditation is little more than a technique for deep relaxation.

The cognitive aspects of meditation are more interesting from a theological point of view. A pointer to the distinctive mode of cognition induced by meditation comes from the classic laboratory studies of Arthur Deikman during the 1960s in which college students gazed at a blue vase while refraining from thinking discursively about the vase in any way. The unusual sensations of vividness experienced were interpreted as arising from a suspension of the normal "automatization" of perception.

Though some meditation moves beyond words and images, much of it still uses them, albeit in an unusual way. Words and images are characteristically used sparingly, but each is allowed to resonate with maximum depth of meaning. Layers of meaning may be uncovered that are felt to be "ineffable." That sense of ineffability may arise from making use of a meaning system of the cognitive architecture that is distinct from, and to an unusual extent decoupled from, propositions that lend themselves to articulation.

See also SPIRITUALITY

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FRASER WATTS

PRIMATOLOGY

Primatology is the study of primates, an order that includes prosimians, monkeys, apes, and humans. Similarities between humans and monkeys were noted already by Aristotle in the fourth century B.C.E., and the Greek physician Galen even dissected a monkey for comparison. In the eighteenth century, Swedish botanist and taxonomist Carl Linnaeus created the order of primates to include monkeys, apes, and humans. The similarity between apes and humans was also noted by Charles Darwin, who argued in *The Descent of Man* (1871) that human beings evolved from an ape-like ancestor.

Even so, relatively little was known about primates until the twentieth century. In 1917, psychologist Wolfgang Kohler published work demonstrating chimpanzees' ability to learn and perform problem solving. In the 1920s, Robert Yerkes established a center for studying primates that was eventually located at Emory University in Atlanta, Georgia. After World War II, significant fieldwork was spearheaded by paleontologist Louis Leakey, who supported research by Jane Goodall with chimpanzees, Diane Fossey with gorillas, and Biruté Galdikas with orangutans. Of the three, Goodall's work has been the most significant, providing remarkable evidence of tool use, social complexity, coordinated hunting, and meat-eating. Modern primatology is a diverse field, involving biologists, anthropologists, and psychologists. Primate species continue to be discovered, and knowledge of many species is comparatively scant.

The question of human uniqueness

While there are many motivations for studying primates, the similarity between humans and other primates has been a key factor in funding and theorizing. Among primates, the great apes (including chimpanzees, bonobos, gorillas, and orangutans) are most similar to humans on anatomical, evolutionary, and genetic grounds. Studies of genetic relatedness indicate that humans and chimpanzees have 98.4 percent of their genes in common, making chimpanzees more closely related to human beings than to gorillas or orangutans. Partly because of this, chimpanzees have attracted far more attention by researchers. Bonobos, a species rediscovered in the 1970s, have also attracted considerable interest in recent years because of their intelligence and unique social behaviors. In virtually all cases, however, the question of the similarity of the great apes to humans has explicitly or implicitly informed research agendas and directions.

The most obvious question of philosophical and theological import raised by primatology is the question of human uniqueness. Since Aristotle (384–322 B.C.E.), philosophers and theologians have frequently claimed that human beings are unique by virtue of their cognitive abilities, especially their abilities for reason, language, and self-consciousness. Work with the great apes, however, has consistently shown that the gap is not as absolute as has been traditionally claimed. Claims of uniqueness based on tool use were the first criterion to go, as fieldwork by Goodall demonstrated that chimpanzees fashioned tools out of blades of grass, which they used to extract termites from termite mounds. Later research has also indicated that chimpanzees in Côte d'Ivoire carefully select appropriate rocks to crack different kinds of nuts.

In the 1970s, extensive efforts were made to teach the great apes versions of sign language and symbolic communication. B. T. and R. A. Gardner's early work with a chimp named Washoe and Francine Patterson with a gorilla named Koko provided mixed results and generated intense controversy as to whether or not apes were capable of producing or merely mimicking language. E. Sue Savage-Rumbaugh used improved methods in the 1980s and 1990s with chimps and bonobos, and her work is seen by many to have established that these apes are indeed capable of true symbolic communication, even though their abilities seem to stop short of full-fledged language.

Other research has focused on the abilities of apes for self and other representation. Experiments by Gordon Gallup indicated that both chimpanzees and orangutans (but not gorillas) are capable of recognizing their images in a mirror. Observations of chimpanzees and other primates in the wild and in zoo settings indicate the ability to deceive, which implies an awareness of one's actions and the effect that they have on others. Efforts to establish by experiment that apes develop models of the thoughts of others (what is called by researchers a "theory of mind") are more controversial and the question remains unsettled.

While research on cognitive abilities is often understood to challenge traditional claims of human uniqueness, research on the social behavior of primates is frequently understood to reveal the evolutionary roots of human nature, altruism, and morality. Expectations that primate sociality was primarily peaceful were shattered by observations made by Goodall that male chimpanzees formed raiding parties and could engage in brutal attacks. Since then, it has come to be recognized that primate societies in general and ape societies in particular are highly complex and stratified. Chimpanzee dominance hierarchies are maintained by group support and mutual aid, but may be usurped by shifting alliances. While some emphasize the negative aspects of this sociality, described by Andrew Whiten and Richard Byrne as "Machiavellian intelligence," primatologist Frans de Waal has emphasized that positive social behavior and altruism are essential to primate societies and, therefore, to human societies as well. In this regard, bonobos in particular have been noted for peaceful coexistence and conflict resolution. At the same time, feminist primatologists and scholars have been concerned to correct sexist bias in the study of primate behavior. Work by Barbara Smuts with baboons revised understandings of sex and courtship in primates. Historian of science Donna Haraway wrote *Primate Visions* (1989) in an effort to deconstruct the ideological bias that has been part of the history of primatology.

Implications for theology

Despite a vigorous science-religion dialogue in the 1980s and 1990s, primatology as a field has been almost completely ignored by theologians. A number of works, however, do cover some of the issues that primatology raises, even if only indirectly. Theologians such as Jay McDaniel and Andrew Linzey have addressed issues of animal rights. Broader themes of evolution and their implication for human nature have also been addressed by a number of theologians, including Philip Hefner, Arthur Peacocke, and John Haught. Works by these authors, however, only partially address the questions that primatology raises, and more theological reflection and analysis remains to be done.

See also ALTRUISM; ANIMAL RIGHTS; ANTHROPOLOGY; EVOLUTION; LANGUAGE; EXPERIENCE, RELIGIOUS: COGNITIVE AND NEUROPHYSIOLOGICAL ASPECTS

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GREGORY R. PETERSON

PROCESS THOUGHT

Process thought emphasizes the ultimate significance of time's forward flow and the change of those things that exist in time. The accent upon time as integral to existence means that process thought considers life to be comprised of events or, as the philosopher William James (1842–1910) would say, "drops" of experience whose character is established by how each becomes. What might appear to be solid matter is really a dance of energy events and interconnections.

Alfred North Whitehead (1861–1947), considered by many to be process thought's chief philosopher, argued that the elucidation of meaning involved in the phrase "all things flow" is one chief task of philosophy. All actually existing "things" change due to their temporality, but the metaphysical principles, mathematic and definitional abstractions, and the essence of God do not change.

Process cosmology

The world is not made up of vacuous substances or wholly self-contained atoms whose relationship to others is entirely external. Rather, argue process thinkers, all actually existing things (events) are internally related to other things. Life itself evolves through mutual influence. Reality is social, but individual events construct the particular factual character of social existence through moment by moment decisions in relationship with others. The process philosophical notion that all existence is interrelated corresponds well with quantum and relativity theories in physics. The interconnectedness of existence is supported by the observation made by physicists that observers of a particular phenomenon produce changes by merely observing the phenomenon.

Comprehending what process thinkers reject may also be helpful when identifying this movement. Process thought rejects the notion that existence is fundamentally comprised of mechanistic, lifeless matter. Instead, process thinkers affirm that existence is organismic, enchanted, and interrelated. The organismic nature of process thought fits well with general evolutionary hypotheses pertaining to the gradual emergence of new and complex species through natural selection, randomness, and adaptation. Process thought affirms that the emergence of highly developed life forms typically entails genealogical connection and descent with modification.

Process thought rejects the claim that creatures are entirely determined or predestined either by the laws of nature, their genes, the environment, or God. Instead, freedom, creativity, novelty, and individual purpose are affirmed because each event is partly self-creative as it responds to the influence of others. Process categories affirm both that individuals are partly self-organized and partly fashioned by others.

Process thinkers typically reject mind-body dualism whereby one's mind or soul is entirely mental and one's bodily members are entirely physical. Process thinkers also typically reject materialistic physicalism, which ultimately denies that mentality and mind exist at all. Instead, many process thinkers speak of mind in nature when adhering to the panexperientialist (or panpsychist) hypothesis proposed by Whitehead and others. The panexperientialist solution to the mind-body problem entails the nondualist hypothesis that all events, including mind events and those events that comprise one's body, have both mental and physical aspects. Events of the same kind can be mutually influencing.

Process views of God

Although most process thinkers are theists, they typically reject theistic doctrines influenced by traditional metaphysical philosophies. The process theologies emerging from the thought of Whitehead and Charles Hartshorne (1897–2000) exert the greatest influence. These two process scholars call God *dipolar* to signify two different dualities: God is influenced by others and influences others, and God is changing and unchanging.

The first dipolarity, God's influence upon the world and the world's influence back on God, is more pronounced in Whitehead's thought. Whitehead speculates that God adds Godself to that from which every creative act emerges. Creatures respond to this divine action, and their response subsequently exerts influence back upon God.

The second dipolarity, God as both unchanging and changing, is more pronounced in Hartshorne's thought. By this dipolarity, Hartshorne means that God's abstract essence is absolute, necessary, and eternal, while God's concrete actuality is everlastingly relative or contingent. The unchanging pole of the divine essence includes attributes that classical philosophical theologies often ascribe to divinity (e.g., necessity, impassibility, infallibility, eternality, and immutability). The changing aspect of God is expressed in God's experience (e.g., suffering, rejoicing, sympathy, and contingency) as deity interacts, moment-by-moment, with creation.

Process thinkers often speculate that God relates essentially with the world, and Hartshorne calls this God-world model *panentheism* (all things are in God). Panentheism is illustrated by the relationship the members of one's body have with one's soul (or mind) because this relationship is analogous to the way the world is in God. Just as the mind naturally interacts with the brain and other members of the body without being ontologically different, so God naturally interacts with the world without being ontologically different. Just as the mind is an actuality distinct from other actualities in the body, so God is an actuality distinct from other actualities in the world.

Process panentheism agrees with classical pantheism by affirming that God is essentially related to the finite order, without agreeing that God's essence requires this particular finite order. It agrees with traditional theism by affirming that God is distinct from and not fully governed by finite relations, without agreeing that God could have chosen not to be in relation with the world. God is essentially immanent in the world because God necessarily influences all. God is essentially transcendent because God's decision about how to react to such influences is not fully determined by them. This divine decision becomes God's influence upon subsequent individuals.

It should also be noted that process thought escapes the "God of the gaps" charge because theistic process thinkers deny that the causal processes of the universe are occasionally filled by divine acts. Instead, process theism supposes that God is always active in the causal processes, although deity never unilaterally determines any particular causal process or the causal processes of the whole. Whitehead expresses these concepts when he claims that God is not an exception to the metaphysical principles designed to save the scheme from theoretical collapse.

See also GOD OF THE GAPS; MIND-BODY THEORIES; PANENTHEISM; PANTHEISM; THEISM; WHITEHEAD, ALFRED NORTH

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THOMAS JAY OORD

PROGRESS

The idea of progress is an invention of the eighteenth century, fueled by discoveries in science and technology. Although it took different forms in different countries, the underlying theme was that, through human effort, it is possible to improve human understanding of the nature of reality. This in turn leads to improvement in the standard of living and of education and health and general well-being. More a metaphysical aspiration than a matter of empirical fact, progress was seen as (and intended to be) a secular alternative to traditional religious views, especially inasmuch as it challenged the notion of a providential God, one who controls completely the future fate of humans according to God's desires and unmerited grace.

Many early progressionists were deists rather than theists, believing in an unmoved mover, who lets the universe run according to unbroken law, rather than subjecting it to God's extra-natural intervention. It was almost to be expected, therefore, that many progressionists were favorable to some form of biological developmentalism, or evolution. Notable were Erasmus Darwin (1731–1802, the grandfather of Charles) and Jean Baptiste de Lamarck (1744–1829). They took the idea of progress in the social and cultural world, read it into the biological world, seeing life's history as an upward movement from the simple (the monad) to the complex (the human being), and then in circular fashion read evolution back into the cultural world as confirmation of their social beliefs about the possibility of intellectual and cultural improvement. It is not surprising that many of the early critics of evolution, notably the French comparative anatomist Georges Cuvier (1769–1832), were as critical of the philosophy of progress as they were of the lack of evidential support for transmutation. Although Cuvier was a Protestant, he was more disturbed by the denial of providence than he was by the challenge to literal interpretation of Genesis.

Charles Darwin (1809–1882), the author of *On the Origin of Species* (1859), in which he put forward his theory of evolution by natural selection, had a somewhat complex relationship with the idea of progress. Socially and intellectually he believed in it absolutely. It is also to be found in his biology, for he clearly regarded humans as the outcome and triumph of evolution. But he realized that his mechanism for change was relativistic. Natural selection means that some will survive and reproduce and others will not, and those that are successful in one situation will not necessarily be successful in other circumstances. Darwin had to invoke the idea of what today's evolutionists call an *arms race,* where there is competition between lines and eventual change and progress—the predator gets faster, and then the prey gets faster. Overall, Darwin thought that this would lead to intelligence and ultimately to humans.

After Darwin, socially and biologically, progress reigned supreme. It was the philosophy of the industrialist and educator alike. In biology, the leading spokesman for evolution was Herbert Spencer (1820–1903), who argued that it is a general law of nature that homogeneity tends towards heterogeneity, and this means that humans are superior to animals, and the English to all other peoples. Many Christian thinkers also started to suggest that perhaps progress and religion are not as opposed as traditionally supposed. If God creates through developmental law, who is to say that God is against the worth and success of human effort? Such particularly were the themes of liberal American protestant preachers like Henry Ward Beecher (1813–1887), as well as of the future Archbishop of Canterbury, Frederick Temple (1821–1902).

The twentieth century saw a major decline in support for cultural and social notions of progress. How could one think in terms of improvement in the face of two world wars, the horrors of Stalinist Russia, Auschwitz, the atomic bomb, global warming, and more? Religious thinkers again increasingly invoked the distinction between progress and providence, arguing that the latter is incompatible with the former. In the between-war years, the Anglican poet T. S. Eliot (1888–1965) explored this theme in depth, and the Jewish philosopher Emil Fackenheim (1916–) made this point repeatedly after World War II. To believe in progress was not simply wrong but immoral.

In biology also the notion of progress became much less prominent. After the coming of Mendelian genetics (which emphasizes the randomness of variation), and the development of what was known as neo-Darwinism or the synthetic theory of evolution, there were far fewer scenarios painting a general sweep upward from the blob to humankind. But one might query whether this decline in visible claims of progress was more a function of a general lack of enthusiasm for the overall idea, or more a realization that the intrusion of social ideas into supposedly straight science is not acceptable. Certainly, the most prominent Christian believer who was also a practicing evolutionist, the French Jesuit paleontologist Pierre Teilhard de Chardin (1881–1955), was an ardent progressionist, following the philosopher Henri Bergson (1859–1941). Among those adopting and endorsing Teilhard's progressivist ideas were such prominent neo-Darwinians as the Englishman Julian Huxley (1887–1975) and the Russian-born American Theodosius Dobzhansky (1900–1975).

The Harvard entomologist and sociobiologist Edward O Wilson (1929–) also endorses biological progressionism. Standing in a tradition that goes back to Spencer, Wilson argues that the evolutionary process gives human beings a backbone on which to build a fully secular substitute for traditional religions like Christianity. For Wilson, progress tells humans where they came from, what status they have in the overall scheme of things (namely the place at the top), and what moral injunctions are laid upon them—to strive to prevent decline and to preserve the human species and, if possible, to send it on to still higher regions of evolution. There have been many critics of this kind of thinking—notably, in biology, Julian Huxley's grandfather Thomas Henry Huxley (1825–1895) and, in philosophy, the early twentieth-century philosopher G. E. Moore (1873–1958)—but in biological circles, if not in general society, belief in progress seems set for the time being. And this probably means that even though such practices may not be in general favor among theologians and Christian believers, there will continue to be those with religious sympathies who attempt to blend progress into their overall world picture.

See also COMPLEXITY; EVOLUTION

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MICHAEL RUSE

PROVIDENCE

The concept of providence expresses the idea that divine knowledge, will, and goodness are at work in the design and governance of the world. Adherents of the Abrahamic traditions, (i.e., Judaism, Christianity, and Islam), characteristically affirm not only that God creates and sustains the world but also that God guides its history toward the fulfillment of divine purposes. The idea of providence, therefore, is closely related to ideas of creation, redemption, and eschatological consummation, as these topics are developed within particular religious traditions.

A distinction has often been made between general and particular (or special) providence. *General providence* refers to God's governance of the universe through the design of creation and the conservation, or sustenance, of all finite things. In establishing the fundamental structures of the created world, God sets the parameters of its history, building in various possibilities and ruling out others. In the modern era, this has often been interpreted in terms of God's role as the creator of the structures of natural law that the sciences seek to disclose. By establishing these causal laws and setting the conditions under which they operate, God directs the developing history of the universe. A theological interpretation of nature, quite without any commitment to the design argument in natural theology, can understand the so-called fine-tuning of the universe as an expression of God's general providence, which orders the world in such a way that life can emerge in the course of cosmic evolution.

Particular providence refers to God's actions within the world's history to advance the divine purposes in specific ways. Each of the monotheistic traditions, for example, includes some form of the story in which God calls Abraham and his descendants into a special covenant relationship that unfolds in an historical drama continuing to this day. The faithful in these traditions typically construe both their individual lives and the history of their communities to be caught up in this ongoing relationship to the providence of God, though it may be difficult to discern God's plan in the apparently chaotic course of history. On some modern interpretations, such as that given by the German theologian Friedrich Schleiermacher (1768–1834), particular providence is understood entirely as the outworking of God's general providence in specific instances. God's purposes for human history are built into the design of creation, and God does not so much act within the stream of historical events as enact history as a whole. This avoids a battery of modern objections to certain sorts of special divine actions (e.g., miraculous intervention). There are theological costs to this interpretation, however, and a number of contemporary theologians have sought ways to conceive of God acting responsively to shape the course of events without intervening in or disrupting the natural order.

Traditional theological accounts of providence agree in affirming the perfection of God's knowledge, power, and goodness in governing the world, but they differ in their accounts of what these attributes entail about God's relation to the course of events. Some doctrines of providence assert that God specifically wills and controls everything that happens; God's sovereign and unconditioned intention for the world embraces all the details of cosmic and human history. Reformation theologian John Calvin (1509–1564), for example, contended that God does not just foreknow but rather foreordains all things, including the destiny of the saved and the damned. This appears to constitute a universal divine determinism, and it triggers the objections, first, that it truncates or eliminates human freedom and, second, that it makes God the cause of human sin, thus compounding the problem of evil. Defenders of positions of this type have usually argued that divine governance of human action, unlike determination by finite causes within the world, does not negate human freedom. Some Thomists argue that because God acts in the utterly unique mode of creator, giving being to creatures and not merely acting as a cause of changes in already existing things, God can bring about a finite event *as* a contingent occurrence or as a free human choice. God wills the human agent's act, but this divine willing does not displace the human agent's freedom, rather it posits the agent and the free act in existence.

Other theologians contend that while all finite things are created and sustained by God and all events are accommodated within God's plan for creation, some events are contrary to God's purposes. On this account, God allows a limited freedom to some creatures, who may act against God's will, but whose misuse of their powers nonetheless falls within the range of possibilities provided for in God's creative purposes. There are various accounts of how this creaturely freedom to act against God's will is nonetheless embraced within God's will, so that God's good purposes remain sovereign in fixing the destiny of creation. In the sixteenth century, Luis de Molina (1535–1600) and his followers developed the view that God's omniscience includes knowledge of what every possible free creature would choose to do under every conceivable circumstance. On this account, God is able to take the free actions of creatures into account in the plan of creation, building in responses that assure the final achievement of the good that God intends. Even if divine omniscience does not include this peculiar type of foreknowledge, some modern thinkers have suggested that God, like a master chess player, is always in a position to incorporate the finite agent's actions into the process of realizing God's purposes. If God's providential governance of history involves this type of responsive action, however, then theologians must grapple with questions about how God's special acts engage and affect the ongoing course of events in the world.

See also DETERMINISM; DIVINE ACTION; OMNISCIENCE; SPECIAL DIVINE ACTION; SPECIAL PROVIDENCE

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THOMAS F. TRACY

PSYCHOLOGY

Psychology is a broad-ranging discipline concerned with human mind and emotion, experience and behavior, and personality development and disorder. It goes back at least to the pre-Socratics of ancient Greece, and has always been a central topic in philosophy. It has also been a concern of many religious thinkers, perhaps especially in the Christian and Buddhist traditions. However, psychology as a distinct autonomous discipline only goes back to the nineteenth century.

After considering the implications for theology of the emergence of psychology as a distinct discipline, three different strands in the relationship between psychology and religion will be examined. First there are theological issues raised by the approach to human nature found within general psychology. Second, there is the investigation of religion using the methods and theories of psychology. Finally, there is the possibility of a psychological contribution to a broad range of topics in theology.

Psychology as science

Modern psychology is self-consciously scientific. It accepted the natural sciences as representing the paradigm of rational inquiry and has sought to mould itself in their image. That has often led to giving priority to mechanistic and materialistic approaches, and to experimental method and repeatable observations.

One key problem for psychology has been deciding what to use as its data. Much psychology is based on self-report data, which includes people reporting their own thought processes and experiences, describing their attitudes or behavior, or completing questionnaires about themselves. Questionnaire research has become the stock methodology of much psychology; it is an easy method to use and has probably been overused.

Other self-report data, such as the clinical data collected by Sigmund Freud (1856–1958), may be rich, but there are serious questions about its dependability. One problem with self-report data is that many people are not reliable observers of themselves; the other is that people may not choose to report accurately what they know.

Psychology has also made much use of observable behavior and performance, including observations of how people perform cognitive tasks and how they interact with other people. There was a period in the early twentieth century when psychology imagined that it could base itself entirely on the observation of behavior, and abandon any attempt to study the human mind. However, *behaviorism,* in its strict form, did not last, and mind was readmitted under the heading of *cognition.* It proved impossible to study even conditioning in rats without inferring mental processes such as expectations. Also, psychologists became increasingly sophisticated in the use of task performance to infer cognitive processes. In this more emancipated climate, self-report data was re-admitted, but used cautiously.

The scientific movement out of which modern psychology arose was explicitly secular in that it deliberately avoided making any religious assumptions. The relation of modern secular psychology to the more explicitly religious psychological reflection that preceded it is a complex matter. Some would emphasize the parallelism between the two. Even though psychology appears to be secular, it can be argued that it is much indebted to its religious past and has often recycled theological ideas in apparently secular form. For example, it has been argued that the concept of original sin lies just below the surface of Freud's avowedly secular psychology.

In contrast, John Milbank has robustly argued that modern social theory, because it is avowedly secular and has no place for God, should be regarded as antitheological and inconsistent with Christian thought. The same might also be said about modern psychology. Against that, however, it could be argued that psychology has become religiously neutral and atheological, capable of being combined either with religious or secular worldviews. The model of science that guided modern psychology in the nineteenth century would now be widely regarded as over-restrictive. However, psychology has gradually become broader, more pluralistic, and more flexible ideologically (i.e., more postmodern).

Psychological approaches to human nature

Psychology contains general assumptions about human nature, and a key issue that arises at the interface of psychology and theology is how compatible are their respective views of human nature. Given the breadth of psychology as a discipline, it is not surprising that it contains a variety of such models, ranging from the biological to the social. Psychology makes use of the radically different methodologies of the social and biological sciences within the same discipline. Not surprisingly, that means that psychology tends to fragment, but it is important that there should be a discipline that tries to hold together these different approaches to the human person. People are both biological and social creatures, and no discipline that ignored one or the other could hope to understand human nature adequately.

There is a tendency for psychology to emphasize the biological aspects of human nature and for theology to emphasize the social and relational aspects. However, a polarized debate should be avoided. An adequate psychology needs to be social as well as biological. Equally, there is no reason why theology should be reticent about the biological aspects of human nature. It is part of the Judeo-Christian tradition, especially in the Old Testament, that human beings come from the "dust" and have much in common with the "beasts." There has been a growing recognition that both theology and psychology in their different ways emphasize the psychosomatic unity of human nature. Theology and psychology both need to hold together the biological and the social aspects of human nature, and could learn from each other's attempts to do so.

One strand of biological psychology seeks to understand human characteristics in terms of their evolutionary origins. There were precursors of this in the sociobiology of Edward O. Wilson (b. 1929), Richard Dawkins (b. 1941), and others; their approach has now been extended into *evolutionary psychology.* A key issue for theology is how strongly reductionist a form evolutionary psychology takes. There is no theological objection to exploring the evolutionary origins of particular human abilities and characteristics, and this has been fruitful in many areas, such as linguistic ability. Problems only arise when it is suggested that the evolutionary approach can explain everything, or that human characteristics are nothing more than the products of their evolutionary origins. Fortunately, cautious research-based approaches to evolutionary psychology are available.

The other important strand of biological psychology is concerned with the brain. Research in neuropsychology has been especially fruitful and has demonstrated close links between cognitive functions and brain activity. The key issue for theology is how this information should be interpreted, which is essentially a philosophical problem. There have been suggestions that the mind and brain are identical, or that mind is an epiphenomenon of the physical brain of no real significance. However, there is no need for psychology to take the kind of strong reductionist approach represented by the biologist Francis Crick (b. 1916), who in 1994 described people as "nothing but a pack of neurons" (p. 3).

Strong forms of social constructionism can be equally reductionist. Human concepts are, of course, the product of particular cultures, and in some respects they are contingent and could be conceptualized otherwise. Further, concepts are psychologically influential, and human experience and behavior is much influenced by how people conceptualize their world. However, there is no need for this to be linked to a nonrealist claim that there is no reality to what concepts represent beyond cultural conventions, or that social constructs completely determine social behavior.

A final area of psychology that carries strong assumptions about human nature is the computer modeling of human intelligence. The analogy between computers and the human mind has been fruitful scientifically and has given cognitive psychology much of its current rigor. However, the indications are that human beings and computers function in such different ways that the analogy between them should not be pressed too far. There is no warrant for asserting that all human functions can be captured in computer form, or that the human mind is nothing but a computer program.

Psychology of religion

The psychology of religion was an active area of psychology in the early days of the discipline and, after a period of decline, has regained some of its former vigor. To realize its potential, it needs to maintain close links with general psychology and apply the most promising advances; generate a broad theoretical approach to religion and relate data to clear research hypotheses; use a range of different methodologies and not rely too much on questionnaire data; and explore the practical applications of psychology for religious life.

The issues about reductionism that arise in general psychology recur in the psychology of religion and can be illustrated in connection with religious experience. There is growing interest in the brain processes involved in religious experience. An example is the research of Eugene d'Aquili and Andrew Newberg, who have analyzed the holistic and causal elements of some types of religious experience and tried to identify their neural substrates. However, whatever progress is made in discovering how the brain is involved in religious experience, there is no reason to conclude that because the brain is involved religious experience has nothing to do with God.

There has also been much interest in the social constructionist approach to religious experience. How people conceptualize experience in religious terms is clearly influenced by the various faith traditions, and may explain the different emphases in religious experiences within different faith traditions, despite the common elements that can also be found. Some have suggested that reports of religious experience are entirely the product of such cultural learning, but there is no basis for asserting that religious experience is nothing more than learning to use a particular set of constructs. Broad-brush social constuctionism is being replaced by sophisticated theory and research on the specific cognitive processes involved in religious modes of understanding.

When particular examples of religious experiences are studied, it becomes particularly clear that it is valuable to combine a variety of psychological approaches. This can be illustrated in relation to glossolalia (speaking in tongues), the best investigated of the charismatic phenomena. There is evidence for an element of social learning, in that people benefit from seeing other people speak in tongues, and get better at it with practice. However, the dissociation of semantics from speech production that occurs in glossolalia suggests an unusual mode of cognitive functioning for which there must be a neurological substrate. There is no incompatibility between approaches from social psychology and from cognitive neuroscience, nor is either of them incompatible with a religious account of the role of the Holy Spirit in glossolalia.

There is currently a growing interest in the evolutionary approach to religion, though as yet it is largely speculative. The capacity for religious experience may well be related to the distinctive capacity for self-consciousness of human beings. It can also be seen as having advantages in natural selection terms through the promotion of social cohesion, moral behavior, mental health, and so on. This is supported by the fact that there is growing evidence that religion is positively associated with good personal adjustment.

The link between religion and personal adjustment becomes clearer if religious people are subdivided, for example into those for whom religion is intrinsic or central to their lives (who have good mental health) and those for whom it is extrinsic or serves other goals (who have poor mental health). Though it is always difficult to move with confidence from correlations to casual conclusions, the mechanisms by which religion might promote good adjustment are becoming clear and include the therapeutic value of religious practices and the support provided by the religious community.

Though religious experience illustrates the breadth of the psychological approach needed in studying religion, it is important to remember the multifaceted nature of religion. There is an equally fruitful psychology of religious beliefs and observances. Psychology has often found it fruitful to study how people differ from one another, and how they develop and change. Both have been central to the psychology of religion.

Psychology and theology

Finally, there can be psychological contributions to theology, although these have not been very fully explored as of 2002. For example, the story of the "fall" in Genesis and the doctrine of original sin invite psychological elucidation. Though the story of the "fall" is widely taken by theologians as making an ontological point about human sinfulness, it can equally well be taken as indicating, in narrative form, the gradual evolutionary development of self-conscious cognitive discrimination, represented by the "knowledge of good and evil." This would be, in a sense, a fall upwards, but it would imply a new capacity to do wrong deliberately, that is, to sin. In addition, emerging self-consciousness would lead to a new awareness of human limitations and fallibility, which would permit human awareness of sinfulness and of separation from God.

Eschatology invites elucidation in terms of the psychology of hope. Though there has been much interest in the relation between cosmological predictions and theological eschatology, it would be a misreading of eschatology to see it as solely concerned with such objective predictions. Eschatology is concerned with a good future that is a gift of God, not just with survival of the universe, and also with an attitude of hope in the present, not just with predictions about the future. Psychology can help to elucidate the nature of eschatological hope. It seems to be not just a matter of optimism (making positive predictions about the future), but a hopeful attitude that can be sustained even when there is little basis for optimism.

There are many theological topics that can be complemented by a psychological approach that does not compete with or displace the theological one. For example, a theology of grace can be complemented by a psychological account of how the benefits of grace work themselves out at a human level. Similarly, a theology of prayer can be complemented by a psychological account of how the activity of prayer helps to transform those who participate in it. The act of thanksgiving, for example, involves a reappraisal, both of the evaluation of experiences as positive or negative, and of the role of God in causal attributions.

See also ARTIFICIAL INTELLIGENCE; BEHAVIORISM; EVOLUTIONARY PSYCHOLOGY; EXPERIENCE, RELIGIOUS: COGNITIVE AND NEUROPHYSIOLOGICAL ASPECTS; FREUD, SIGMUND; MIND-BRAIN INTERACTION; NEUROPHYSIOLOGY; NEUROSCIENCES; PSYCHOLOGY OF RELIGION; SELF

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FRASER WATTS

PSYCHOLOGY OF RELIGION

From the perspective of science and religion, there exist three kinds of psychology of religion. *"Secular" empirical psychology* (e.g., Hood) – the most widely practiced – excludes the question of the transcendent and researches religious experiences and behavior in terms of meaningful psychological concepts such as cognition, emotion, motivation, attribution, social interaction, and development. The two other kinds are more mission-oriented. *"Theistic" religious psychology* (e.g., Koteskey; cf. Reich) includes the transcendent and aims to understand God's creation and make people more God-like by improving their mental functioning, their moral judgment, their empathy and so forth. *"Atheistic" psychology of religion* (e.g. Kurtz; Vetter) aims primarily to demonstrate the illusion of a perceived transcendent and the regressive and oppressive effects of being religious.

See also FREUD, SIGMUND; PSYCHOLOGY; SELF

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K. HELMUT REICH

PUNCTUATED EQUILIBRIUM

An addition to the neo-Darwinian theory of evolution proposed by paleontologists Stephen Jay Gould and Niles Eldredge in 1972, punctuated equilibrium is intended to explain the lack of intermediate steps in fossil records. Gould and Eldredge propose that biological species do not evolve gradually (as in gradualism) but exist in a state of stable equilibrium (stasis) with no or very slow evolution followed by a burst of fast evolution that quickly, by geological timescale, results in the formation of new species. Gould and Eldredge also suggest that not all evolutionary changes are adapted (as in adaptationism) and that some evolution occurs at the level of species. Punctuated equilibrium is sometimes confused with saltationism, evolution by sudden large changes due to macromutations.

See also CATASTROPHISM; EVOLUTION; GRADUALISM

ARN O. GYLDENHOLM

Q

QUANTUM COSMOLOGIES

Quantum cosmological theories attempt to extend Albert Einstein's theory of gravitation to include quantum theory. There have been many attempts to carry out this extension of Einstein's work and as yet there is no single satisfactory theory. A quantum cosmology is needed in order to draw conclusions about the nature of the initial state of the universe and to interpret the meaning of the idea that it might have quantum-mechanically tunneled out of "nothing," or some version of the quantum vacuum. A quantum cosmological theory is expected to be a particular application of a full theory of quantum gravity (sometimes referred to as a "theory of everything") that would unite and extend all existing theories of the forces of nature. The favored candidate for such a theory at present is *M-theory,* a version of the theory formally known as superstring theory. Theories of this sort are highly constrained by mathematical requirements of symmetry and finiteness, as well as by the requirement of explaining all known elementary particle physics. Quantum cosmologies lead naturally to the Many-Worlds Interpretation of quantum mechanics.

See also COSMOLOGY, PHYSICAL ASPECTS; GRAND UNIFIED THEORY; SUPERSTRINGS

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JOHN D. BARROW

QUANTUM FIELD THEORY

Quantum field theory is obtained by combining special relativity and quantum mechanics. Until 1981 this was the primary tool for the understanding of elementary particles of matter and the non-gravitational forces of matter. However, such theories were known to possess deficiencies and many calculations of observable quantities led, formally, to infinite answers. Yet, by the application of well defined rules these infinities could be removed to leave finite answers that agree with observation to as many as fourteen decimal places of precision. It was then discovered that these deficiencies could be avoided by replacing their theories of pointlike particles by string theories that treated the most fundamental entities in nature as lines or loops of energy (*strings*) possessing a certain symmetry (*supersymmetry*).

String theories avoid the infinities and paradoxes of quantum field theories and are a promising candidate for a complete theory of all elementary particles and forces of nature. The stringlike loops of energy in these theories possess a tension that increases as the temperature of the environment falls. Thus at very high temperatures, for example in the first moments of the expansion of the universe, they would have behaved in an intrinsically stringy manner. As the universe expanded and cooled, the string tensions would increase and the loops of string would behave more and more like single points of mass and energy. As a result, in the low temperature world all the predictions of the earlier quantum field theories are expected to be obtained, in agreement with experiment.

See also PHYSICS, QUANTUM; FIELD THEORIES; STRING THEORY

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QUANTUM MECHANICS

See PHYSICS, QUANTUM

QUANTUM PHYSICS

See PHYSICS, QUANTUM

QUANTUM THEORY

See PHYSICS, QUANTUM

QUANTUM VACUUM STATE

The Heisenberg Uncertainty Principle allows for the rapid creation and annihilation of particles even in a vacuum, which is by definition the state of lowest possible energy. Careful experimentation has confirmed that this picture of the vacuum as a sea of virtual particles is accurate. For example, it explains the so-called Casimir force between two metal or dialectric plates and the so-called Van de Waal's force in chemistry. This conception of the vacuum is significant for philosophical and religious cosmologies in at least three ways. First, the concept of the quantum vacuum suggests a picture of a primeval chaos of virtual particles being tamed and ordered by conservation laws—the opposite of the classical picture in which a quiescent, perfectly well-ordered state lies beneath the chaos of matter and energy, with implications for the idea of creation in western religious traditions. Second, Daoist interpretations of reality as emergent from an inexpressible state of highly structured dynamism seem resonant with the idea of the quantum vacuum. Third, Buddhist ideas of dependent coarising from emptiness seem amenable to interpretation in terms of the quantum vacuum state. Each of these possibilities, and others besides, needs thorough study.

See also HEISENBERG'S UNCERTAINTY PRINCIPLE

NIU SHI-WEI

R

REALISM

Realism is the doctrine that existence is separate from conceptions of it. People may think and talk of different entities, but the entities themselves have a reality that is logically independent of thought and language. This may seem a matter of common sense; surely chairs and tables do not exist only in so far as one thinks of them, or perhaps perceives them. People do not conjure things into existence through their minds, in the way that dreams create a world that vanishes when one wakes up. Yet to appeal to common sense is to appeal to the philosophical views of previous generations that have gained common currency. The position itself needs some philosophical justification. Dr. Samuel Johnson is supposed to have dealt with Bishop George Berkeley's idealism by simply kicking a stone and exclaiming "I refute it thus!": This is hardly an argument.

Contention with idealism

Realism is in fact most often opposed to idealism. The latter claims that all reality is a construction out of mental processes. As Berkeley (1685–1753) said in his *Treatise Concerning the Principles of Human Knowledge,* "To be is to be perceived." In other words, what exists does so because it is perceived, and is not perceived because it exists. The latter would be the realist position. Yet Berkeley's position not only makes all reality mental, it also restricts what can exist to what is within the range of someone perceiving it. Berkeley met this by appealing to the omniscience of God, so that everything is perceived by God, and therefore exists. The danger is that God is removed from the picture; this is a move empiricism tends to encourage. The view then becomes one that ties reality to actual or possible human experience. This, in turn, makes reality anthropocentric. What humans cannot perceive cannot exist. Since contemporary physics wishes to deal with subatomic particles and other unobservable entities, such as, say, the interior of a black hole, this does not seem to give an adequate account of the assumptions of present-day science.

Although realism may be classically opposed to idealist tying of existence to mind, realism comes in many shapes and sizes. It can be a global, metaphysical doctrine, or it can be limited to particular areas of human activity. One could be a realist about the objects of scientific investigation, but not about the concerns of morality. The main point of realism, though, is always to pull apart the fact of existence from issues concerning how anyone can know what exists. Ontology and epistemology should not be confused. (So-called critical realism tends to link the two). The metaphysical realist will stress the objectivity of the "world" or whatever exists. It cannot depend in any way on the way people think about it or discover it. Even scientific realism may seem realist in its insistence on the independent reality of the objects of science. It can, however, become antirealist when it asserts that only the objects of science can exist. In other words, existence is then restricted to what lies within the scope of actual or conceivable science. Because that must be human science, reality is being artificially restricted to what is within the scope of human capabilities to discover.

Ontological bases of science and religion

The focus of realism must always be reality, and not issues of how one can come to know reality. Otherwise questions about existence become changed into questions about human abilities. What lies beyond human abilities cannot even be conceived to exist. A major motive for scientific research is the knowledge of human ignorance. The world is not limited to present knowledge, nor to what people are able to discover. This becomes of crucial importance in the field of religion, which is normally understood as attempting to talk of what is transcendent, or ontologically separate, from the world with which people are normally familiar. Empiricist philosophy from the time of David Hume (1711–1776) has attempted to restrict language to what is within human experience. This is always to change the subject from reality to human knowledge. Yet realism cannot rest content with metaphysical assertions about the status of reality. A reality to which people are oblivious is no better than nothing at all. Ontology needs epistemology: It is just not identical to it.

Both science and religion need a strong realist underpinning. They must be about something. Science has to assume that it is investigating a world that has an independent existence. Otherwise it is a mere social construction reflecting the conditions of particular societies at a particular time. Similarly, any religion must assume that it is concerned with a reality that is not the creation of human imagination. Theism must have a realist outlook. It is making claims about an objective reality that are contradicted by atheism, itself also a realist view. Indeed, if God or other spiritual realities are mere projections of human thought or language, religion is guilty of a massive bout of wishful thinking. If the realities described do not actually exist, there is no ground for any cosmic optimism. The antirealist may complain that this is already assuming a realist interpretation of religion. Yet, the idea that neither religion nor science engage with anything beyond themselves seems to negate their most important function of claiming truth. If they are conceived of as conceptual schemes, practices, or forms of life, with no external justification, there seems no point in taking part in them. There can be no justification or reason for being religious, or doing science.

According to realist understanding, however, there is an independent world for both science and religion to relate to. Moreover, each purports in various ways to describe parts of the same objective world. This in itself provides sufficient ground for trying to show connections between the two. Whatever their distinctive methods, one can not rule out either the possibility of conflict or of mutual support. For example, if this is God's world, this might give an explanation for the inherent order and regularity, which science needs to assume, in order to generalise from particular findings.

See also CRITICAL REALISM

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ROGER TRIGG

REDUCTIONISM

When theoretical statements use terms that refer to objects and properties whose existence seems awkward, puzzling, redundant, or ontologically problematic, there is motivation to analyze or *reduce* such statements to others that employ better understood terms. Reductionism must be distinguished both from *eliminativism* and *supervenience*. Consider two domains of properties *M* and *P* (e.g., the mental and the physical). Eliminativism claims that since only *P* exists, *M* can be eliminated (e.g., there is no such thing as demonic possession, but only a biochemical problem in the brain). Supervenience asserts that both *M* and *P* are real and distinct, though *M* is determined by *P* (e.g., headache pain is real, and while not identical to neurophysiological processes, is nonetheless realized by such processes). Reduction, however, asserts that there is but one thing that is both *M* and *P,* with *P* having explanatory priority (e.g., Mary's particular headache pain is just a particular complex neurological event).

Semantic and theoretic reduction

Examples of reductions in philosophy include *logicism* (reducing statements about numbers into statements of logic and set theory), *phenomenalism* (reducing statements about external macro-objects into statements of actual and possible experience), *logical behaviorism* (reducing statements about mental states into stimulus-response conditionals), *logical positivism* (reducing statements employing theoretical entities to ones referring only to observed objects), and *naturalism* (reducing normative ethical statements to ones whose terms refer to natural properties only). All these philosophical reductions are semantic, for all use definitional equivalences linking terms of the reduced to those of the reducing statements, (i.e., statements in the reduced theory just mean equivalent statements in the reducing theory). Broadly speaking, semantic reductions have been out of favor in philosophy since the 1950s. This is due in part to four developments: the heightened sensitivity to the "paradox of analysis" (i.e., if a semantic reduction is successful it is not informative and if it is informative it cannot be successful); the realization of the enormous practical difficulties of actually carrying out the proposed reductions; an increasing recognition of the holistic nature of sentence meaning; and the growing doubt about the very possibility of foundational discoveries.

Of more interest to the science-religion conversation is the status of scientific reductions. Consider physics, chemistry, biochemistry, biology, physiology, neuroscience, psychology and sociology. How are these various disciplines related? How does one connect hadrons, atoms, chemical compounds, amino acids, cells, synapses, thoughts, and cultural tendencies? If physicalism is true in asserting that all that ultimately exists are those entities referred to in the most basic physical theory, then in what sense can thoughts and cultural tendencies exist? Should talk of such things be eliminated, or should we understand theories making reference to them to be reducible to more basic theories, and ultimately to theories referring to fundamental physical entities? Theoretic reduction in the philosophy of science attempts to show how entire theories, and the entities and properties specified by them, are reducible to more basic theories.

Unlike semantic reduction, theoretic reduction understands the biconditionals connecting theoretical terms in the reducing and reduced theories to be empirically discoverable bridge laws specifying coextensive property instantiations. While statements in the reduced theory mean something different from statements in the reducing theory, it is nonetheless true that the reduced theory statements are true if and only if their reducing statements are true. Examples of theoretical reduction within science include the reduction of chemistry to physics, the reduction of thermodynamics to statistical physics, the reduction of Mendelian genetics to molecular genetics, and the partial reduction of psychiatry to neurophysiology.

Reductions can also be found in theology and religion, though they are not often presented as such. For example, Immanuel Kant (1724–1804) semantically reduced talk of God to discourse about morality, while Friedrich Ernst Schleiermacher (1768–1834) reduced it to modifications of the feeling of absolute dependence. Karl Marx (1818–1883), Sigmund Freud (1856–1958), and Emile Durkeim (1858–1917) attempted theoretically to reduce religion to economics, psychology, and sociology respectively.

Varieties of reduction

There are different types of reduction, and also different typologies of these reduction types. One might distinguish methodological, epistemological, and ontological reduction. Accordingly, the first is a research strategy in which the behavior of complex wholes is analyzed into their component parts; the second an explanatory strategy claiming that theories and laws at the higher levels are analyzable or otherwise explainable in terms of the theories and laws of the lower levels; and the third an ontological strategy holding that reality is ultimately comprised of nothing but simple components (e.g., quarks, strings) organized in particular ways.

This "nothing but" relation can be understood as reduction's defining characteristic: *M* reduces to *P* if and only if *M* is nothing but *P*. Accordingly, one can distinguish ontological, property, semantic, theoretical, and causal reduction. Ontological reduction claims that upper-level entities and events are nothing but complex configurations of lower-level entities and events; property reduction asserts that the instantiation of every upper-level property is nothing but the instantiation of a particular lower-level property; semantic reduction declares that the meaning of statements in the reduced theory is nothing but the meaning of statements in the reducing theory; theoretic reduction claims that laws of the reduced theory are nothing but the laws of the reducing theory; and causal reduction asserts that the causal powers of upper-level entities are nothing but the causal powers exhibited by their lower-level physical realizers.

Property reduction and causal reduction are of particular interest in the science-theology discussion. One can hold that while only physical particulars exist, property dualism nonetheless obtains because higher-level properties are not reducible to, and thus not coextensive with, any specific lower-level properties. Some in the science-theology discussion believe such a nonreductive physicalism of emergent mental properties can protect religious discourse and experience from reduction or elimination.

Causal reduction is extremely important for the question of the ontological status of putative emergent entities and properties. If entities at the upper-levels wholly inherit their causal powers from the lower-levels, and if ontological status only pertains to causally efficacious entities, then it seems that emergent phenomena are not fully real. The question of the causal status of emergent properties is at the heart of the controversy about downward causality. Some in the science-theology discussion suggest that the emergent itself can effect the causal distribution at the lower-levels, not just the lower-level realizers of that emergent, (e.g., consciousness itself is causally efficacious.) But if particular lower-level actualizations are sufficient for the instantiation of an emergent property, then it seems that these actualizations are also sufficient for the effects this emergent property is said to cause.

Conclusion

Many in the science-theology discussion wish to provide an account of emergent phenomenon that does not presuppose reductive explanation. Unfortunately, even in the absence of the straightforward reduction of the emergent, the admission of its physical realization seems to accomplish much of what reduction initially sought, for the causal loop still gets closed at the lowest physical levels. It seems that the "something more" of the emergent may be "nothing more" when it comes to the issue of causal reduction. This is not a result that would cheer many in the science-theology conversation.

See also BEHAVIORISM; CAUSALITY, PRIMARY AND SECONDARY; CAUSATION; DOWNWARD CAUSATION; MATERIALISM; NATURALISM; PHYSICALISM, REDUCTIVE AND NONREDUCTIVE; SUPERVIENIENCE

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DENNIS BIELFELDT

REDUCTIVE PHYSICALISM

See PHYSICALISM, REDUCTIVE AND NONREDUCTIVE

REINCARNATION

Reincarnation or *samsara* is the beginningless cycle of birth, death, and rebirth. The rebirth idea follows from the traditional Yoga psychology concept of *karma,*the memory trace or "seed" laid down in the unconscious by each freely chosen action or thought, which is stored until the opportunity arises for it to sprout forth as an impulse to do a similar action or thought again. The unconscious contains all the karmic seeds laid down during this life and from all previous lives. The presence of such *karmas* and their impulse to sprout is the cause of one's rebirth. Removal of *karma* from one's unconscious by spiritual discipline (*Yoga*) results in release (*moksa*) from rebirth. Originating from Hinduism, this idea was adopted by Jainism and Buddhism in India, and is also found in Platonic thought.

See also HINDUISM; KARMA; LIFE AFTER DEATH

HAROLD COWARD

RELATIVITY

See GRAVITATION; RELATIVITY, GENERAL THEORY OF; RELATIVITY, SPECIAL THEORY OF

RELATIVITY, GENERAL THEORY OF

Albert Einstein radically reshaped the understanding of gravity through his proposal of the General Theory of Relativity in 1916. The problem he tackled was to create a theory of gravity that was consistent with his Special Relativity Theory, including its radical transformation of the understanding of space and time measurements through the introduction of a unified concept of space-time. Special relativity is based on the invariance of the laws of physics under any constant change of velocity, and hence the equivalence from a physical viewpoint of all uniformly moving (non-accelerating) observers. General relativity extended these ideas to a special class of accelerating observers.

Einstein's insights

Einstein's first brilliant insight was that, in consequence of Galileo Galilei's (1564–1642) discovery in the seventeenth century that all falling bodies near the Earth accelerate at the same rate, any uniform gravitational field can be transformed away (i.e. made to vanish) by changing to a suitably accelerating reference frame; indeed for any observer in free fall, gravity effectively ceases to exist. We have seen this in films of astronauts in free fall, where gravity does not seem to act (objects float freely in the air), even though they are in spacecraft that are relatively close to the surface of the Earth, where the gravitational field is strong enough to make the spacecraft move in a circular orbit.

Thus, from a physical viewpoint, inertial and gravitational effects are indistinguishable; this is Einstein's Principle of Equivalence. There is no invariant gravitational force, in analogy to the electromagnetic force, but rather effective gravitational forces are felt by observers in consequence of their choice of reference frame. One consequence is the prediction of the phenomenon of gravitational *redshift* (a shifting of light toward the red end of the spectrum as a result of a gravitational field rather than a relative velocity). This has been verified by high accuracy measurements on Earth.

Einstein's second major insight (building on previous work by others, particularly German mathematician Georg Friedrich Riemann [1826–1866]) was that the principle of equivalence could be made compatible both with experimental evidence concerning gravity and with the special theory of relativity by embracing the idea that space-time is curved. Freely falling objects and light rays move on geodesics in curved space-time, that is, curves whose space-time direction is unchanging (these curves are the closest that one can get to a straight line in a curved space-time). When projected into surfaces of constant time, these paths can appear highly curved; indeed, the nearly circular motion of the Earth around the sun is the result of the Earth moving in an undeviating direction in the curved space-time around the sun. A consequence is the prediction of the bending of light by a gravitational field, which was verified in a famous experiment in 1917, when bending of light by the sun was measured during a solar eclipse. This bending leads to gravitational lensing of distant objects (quasi-stellar objects and galaxies) by nearer galaxies and cluster of galaxies, resulting in distorted images and multiple images.

Einstein's third major insight was that the space-time curvature is determined by the matter in it. This is a major revolution in our understanding of the nature of geometry. Previously, the geometry of space (and space-time) had been assumed to be fixed and invariant, a purely mathematical construct. Einstein's proposal meant that space-time geometry varies according to the matter present; consequently geometry became a branch of physics. Einstein spent many years pondering the nature of this relation, and eventually completed his theory by proposing his gravitational field equations, which relate the stress-energy *tensor* of the matter present to space-time curvature. (A tensor is a physical quantity that has many components that, taken together, characterize its nature. The physical energy tensor combines in one quantity the energy density, quantum density, isotropic pressure, and anisotropic pressures characterizing a fluid. These quantities combine in different ways when different reference frames are used.) This theory can predict the motion of planets around the sun more accurately than Newtonian theory can, explaining in particular the anomalous precession of the perihelion of the planet Mercury. Indeed Einstein's theory has been tested with high precision in the solar system and has passed all observational tests with flying colors.

Predictions of the theory

The General Theory of Relativity also predicts radically new phenomena. Firstly, black holes are predicted to result at the end-point of the lives of massive stars when they have burnt all their nuclear fuel. Black holes are objects where the gravitational field is so strong that light cannot escape; a radially outgoing light ray will be halted and will fall back in to the center. Consequently an outside observer receives no light or radiation from the interior and cannot observe what is going on there. The gravitational field at the center will become so strong that a space-time singularity occurs. It is believed that black holes have been detected through the X-ray emissions associated with hot dust falling in across the event horizon, which is the surface bounding the black hole region. Any object crossing the event horizon to the interior cannot then escape; it is doomed to fall into the singularity. It is now believed that black holes exist at the center of many galaxies, including our own, and provide the power sources for incredibly luminous quasi-stellar objects. Secondly, gravitational waves will be generated by the motion of astronomical objects such as binary pulsars. It is difficult to detect them directly because they are extremely weak, but they have been indirectly detected because of their effect on the orbits of a binary pulsar (Russell Hulse and Joseph Taylor were awarded the 1993 Nobel Prize in physics for this observation). A new generation of gravitational wave observatories are being constructed, and it is hoped they will detect gravitational waves within the next ten years.

A problem with the theory is that it predicts that under many conditions (e.g., at the start of the universe, and at the end of gravitational collapse to form a black hole), space-time singularities will occur. Scientists still do not properly understand this phenomenon, but presumably it means that they will have to take the effect of quantum theory on gravity into account in some suitable generalization of general relativity, which is a purely classical theory. Additionally, general relativity in principle allows a variety of causal violations to occur (e.g., you can travel through space-time in such a way as to talk to your grandfather when he was ten years old). There is considerable debate on how to regard this feature.

The Einstein equations are extraordinarily unique, but they do allow the possibility of a cosmological constant (effectively, a very weak long-range repulsive force). This has been the subject of dispute ever since Einstein included it in his equations in 1917 in order to allow a static universe solution. He abandoned it when the expansion of the universe became generally accepted, but it keeps recurring in various forms, for example in the inflationary universe idea. There is good observational evidence that the recent expansion of the universe is dominated by a cosmological constant, however the physical origin of this universal repulsive force is unexplained. From the viewpoint of quantum field theory, its existence is highly problematic.

See also BLACK HOLE; COSMOLOGY; EINSTEIN, ALBERT; GRAVITATION; INFLATIONARY UNIVERSE THEORY; RELATIVITY, SPECIAL THEORY OF; SPACE AND TIME

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GEORGE F. R. ELLIS

RELATIVITY, SPECIAL THEORY OF

The Special Theory of Relativity describes the way in which an observer's experience of time and space is interrelated, while the General Theory of Relativity addresses the interrelationships among mass, space, gravity, and motion. Motivated by his concerns about problematic features of electromagneticism—especially the relationship between electric and magnetic fields—Albert Einstein (1879–1955) proposed the Special Theory of Relativity in 1905. However, since most of the character and consequences of Special Relativity can be more easily developed in the arena of kinematics (the description of motion), this entry will focus on the ways in which motion influences the outcome of measurements regarding space and time.

Inertial reference frames

The term *reference frame* ordinarily refers to a *coordinate system* (like the Cartesian system with three mutually perpendicular axes labeled x, y, and z) in which the location and motion of an object can be conveniently described, along with a set of synchronized clocks with which to determine the time at any location in that coordinate system. Given such a reference frame, one can specify the coordinates of any event E by stating its location (x, y, z) and the time (t) of its occurrence in the notation: $E(x, y, z, t)$.

Of all possible reference frames, Special Relativity is concerned only with *inertial reference frames*—reference frames in which Newton's First Law (sometimes alled the Law of Inertia) holds. It can be shown that any reference frame that moves with constant velocity (constant speed and direction) relative to an inertial frame is also an inertial reference frame.

Postulates

Einstein's Special Theory of Relativity proceeds from two fundamental postulates regarding the results of comparing the observations of physical phenomena (sets of events) by observers in two or more inertial reference frames. These two postulates may be stated as follows: (1) The speed of light is the same in all inertial reference frames, independent of the motion of the source; and (2) The form of all physical laws (not only those pertaining to mechanics) is the same in all inertial reference frames. The first postulate represents a break from the common expectation that the speed of light relative to its source would be fixed, as would be the case for a bullet fired from a gun. The second postulate represents a significant extension of the classical principle of relativity that applied only to the laws of mechanics.

Predictions

From these two postulates a number of fascinating predictions can be deduced.

The relativity of simultaneity. The *Lorentz transformation,* named after Dutch physicist

Hendrik Anton Lorentz (1853–1928), is a set of equations that allows the calculation of event coordinates in one reference frame from the coordinates of the same event in another frame. Suppose that in reference frame *S* an observer notes two events that occur at different locations, but at the same time. The *S* observer says that these two events occurred simultaneously. Then consider another reference frame *S′* that is moving at a constant velocity relative to *S.* Applying the Lorentz transformation to the event coordinates in *S* to obtain the coordinates for the same two events in *S′* leads to a remarkable result. Observers in *S′* would say that these two events occurred at different times. That is, events that appear simultaneous in one inertial reference frame would not be observed as simultaneous in any other inertial frame. The amount of time separation would depend on the relative speed of the two frames. Simultaneity is not absolute, but is dependent on the observer's reference frame. In other words, there is no universal time on which all observers can agree.

Length contraction. Consider a meter stick oriented parallel to the *x* axis of a references frame *S* that is moving at speed *v* along that same *x* axis. Let *S′* now be a reference frame attached to the meter stick. An observer in *S′* affirms that the length of this stick, at rest in *S′*, is one meter. Now suppose that an observer in *S* wishes to measure the length of the stick that he observes to be moving at speed *v.* This must be done by noting the locations of the two ends of the stick simultaneously in *S* and calculating the distance between these two locations. Doing so, however, would lead to the interesting result that, as measured in *S,* the length of the meter stick is less than one meter. This is the phenomenon called *length contraction.* The measured length of a moving object is contracted in the direction of its motion. Dimensions perpendicular to the direction of motion are not affected.

Time dilation. Using the same notation for reference frames *S* and *S′*, consider a clock that is at rest in *S′*. Relative to any observer at rest in *S,* that *S′* clock is moving at speed *v.* As it moves, it passes numerous *S* clocks that are distributed throughout reference frame *S.* Suppose that the *S′* clock was synchronized to display exactly the same time as one particular *S* clock at the instant the *S′* clock passed it. Now suppose that at some later time, the display of the *S′* clock is compared with a second *S* clock as it passes it. Once again, applying the Lorentz transformation to predict the coordinates of this second clock-passing event leads to a surprising result: The *S′* clock will lag behind the second *S* clock. A moving clock (the *S′* clock is moving relative to reference frame *S*) records less elapsed time than do stationary *S* clocks. This is the phenomenon called *time dilation.* Numerous empirical tests have affirmed this peculiar effect.

There is a symmetry that must be acknowledged in regard to the time dilation phenomenon. Comparing equivalent observations by observers in two different reference frames, each would say (with justification) that the clocks of the other were running slowly. That symmetry has led some persons to question the idea of twins with differing motion histories actually achieving different ages. The standard scenario for the so-called twin paradox posits a pair of twins with a keen interest in testing relativity theory. While one of the twins stays at home, the other takes off in a rocket and travels at a substantial fraction of the speed of light for a few years, as measured on his own calendar watch, and then turns around to reverse the trip. Upon reunion with his twin, how will the age of the traveler compare with the stay-at-home sibling? From the viewpoint of the homebody, the traveler's clocks have been running slowly for most of the trip, both outbound and inbound (the direction of travel is irrelevant). So, it would seem that at the reunion, the traveler would be younger than his homebound twin. However, what about looking at things from the standpoint of the traveler? Would it not be the case that the homebody's clocks were running slowly so that the homebody would be the younger sibling at reunion? That's the usual presentation of the twin paradox—conflicting conclusions flowing from the symmetry of the time dilation phenomenon.

It turns out, however, that there is no actual paradox, no conflicting predictions. The traveler really is the younger at reunion. There was no effective symmetry in the motion histories of the twins. One stayed in a single reference frame the entire time; the other accelerated from one frame to another several times. The amount of time elapsed between the twins' separation and reunion events will be different for each as a consequence of differing histories of motion. Strange, perhaps, but apparently true.

The mass-energy relationship. If there is one mathematical relationship that best characterizes the popular conception of special relativity it would have to be the equation $E = mc^2$;, where E represents energy, m represents mass, and c is the speed of light. But what does this familiar equation actually signify? In very general terms it signifies that mass is one particular form of energy and that it could, given suitable circumstances, be transformed into other forms of energy. Nuclear reactors, for example, provide the circumstances for a controlled transformation of some of the mass-energy of selected radioactive nuclei into heat, which is then used to drive conventional electrical energy generators. In a similar way, a coal-fired power plant accomplishes the same transformation of mass-energy into heat by means of chemical rather than nuclear reactions.

There is more, however, in the familiar $E = mc^2$. The mass, m, that appears in this equation is the *relativistic mass,* whose value depends on the speed of the object under consideration. In fact, as an object's speed, v, approaches the speed of light, the value of its relativistic mass approaches infinity. In effect, that means that it would require an infinite amount of energy to accelerate an object to the speed of light. With only finite amounts of energy available, the speed of small objects (such as atomic constituents) can be increased (in a particle accelerator device) to a value approaching the speed of light, but never equaling or exceeding it. Nothing having mass can be given a speed relative to a local observer that is equal to or greater than the speed of light. This is a speed limit that is enforced not by legal decree, but by the very nature of the universe itself—specifically the relationships among space, time, motion, and energy.

This speed limit applies only in a localized region of space. If one is considering the motion of extremely distant objects, say billions of light-years away, another factor must be included—the expansion of space itself. In the language of General Relativity, space is not merely a nothing in which things may be placed, but a specific something that has properties and is able to act and be acted upon. One of the things that cosmic space is doing, apparently, is expanding. Distant galaxies are observed to be receding from the Earth because the space between them and the Earth is expanding. The motion of distant galaxies that can be attributed to this spatial expansion phenomenon is not restricted by the speed of light limitation just discussed.

Implications for religious thought

The theory of relativity must be clearly distinguished from what is ordinarily denoted by the word *relativism.* Moral relativism, for instance, presumes that there are no universal standards of right and wrong behavior. Likewise, epistemic relativism presumes that there are no observer-independent standards for objective knowledge. As noted above, however, the special theory of relativity entails no denial of standards for comparing the observations of various observers. On the contrary, relativity theory specifies those standards with great clarity. Relativistic mechanics differs from classical mechanics not by abandoning standards, but by offering a specific and new set of standards that bring predictions and observations into agreement.

Another feature of Special Relativity theory that suggests an application to religious thought is its demonstration of the fact that common sense sometimes needs to be corrected. Most people have common sense notions of space and time that function perfectly well as they go about their daily routines of life. People use these notions as they plan their travels from place to place and as they proceed throughout the course of a day. These common sense notions include the following:

(1) All impartial observers should agree on the time interval between two events.

(2) All impartial observers should agree on the distance between two points.

(3) Things can always be made to go faster.

(4) Twins remain equal in age no matter what they do.

However, each of these expectations turns out to be incorrect, and concepts of space and time must be modified in order to comprehend what careful observations and measurements have revealed.

The origin of such shortcomings in common sense notions of space and time is easy to identify: These notions are based on limited experience. Until physicists performed observations and measurements on particles moving at speeds approaching the speed of light, the shortcomings of human concepts of space and time could not be detected. Extending human experience with space, time, and motion into new speed regimes revealed those shortcomings and inspired modifications of the sort proposed by Lorentz and Einstein. The lesson is evident: Epistemic dogmatism (I have the complete and final understanding of *X*) must often be replaced with epistemic humility (what I now think I know may someday need to be modified in response to an expansion of experience). This is not to despair and claim no knowledge whatsoever. This is rather to remain open to correction, even while celebrating the knowledge of the day. On these matters theology and science enjoy full agreement.

See also EINSTEIN, ALBERT; RELATIVITY, GENERAL THEORY OF; SPACE AND TIME

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RELIGION AND VALUES, ORIGINS OF

The word *value* expresses worth in a broad generic sense, but this usage only dates to about from the mid-nineteenth century. The classical meaning of *value* was more limited, referring to goods, excellence, riches, benefits, utilities. The word *value* occurs in the Bible almost always translating Hebrew and Greek economic terms referring to price. The word *religion* includes the Latin root *liga* (also in *ligament* and *obligation*), which means *binding,* here intensified by the prefix *re-*. Hence, religion is that to which one is most deeply bound. "The essence of religion," claims Harald Höffding, "consists in the conviction that value will be preserved" (p. 14). If one finds a world in which value is given and persists over time, one has a religious assignment. A central function of religion is the conservation of fundamental values. Frederick Ferré defines religion: "One's religion . . . is one's way of valuing most intensively and most comprehensively" (p. 11).

Genesis of value in natural history

A frequent claim is that science deals with causes, religion with values. That is an overstatement: Scientists evaluate better and worse science; theologians ask whether divine agency can be detected in natural history. Nevertheless, natural science is a systematic study of causes in nature; religion is a life-orienting inquiry into meanings of life in the world. But these crisscross.

In the course of natural history, "mere" causes (operating in rocks, winds, waters) generate life, events of deepening significance (DNA molecules coding for adapted fit). Where once there was matter, energy, and where these remain, there appears information, symbolically encoded, and life. Signals emerge. A rock conserves no identity. An oak tree, by contrast, conserves a metabolism and an anatomy over time. Organisms are self-maintaining systems. There is a new state of matter, neither liquid nor gaseous nor solid, but vital.

Speciation generates biodiversity; some species become increasingly animated with neural evolution, evolving felt experience. *Homo sapiens* develops capacities for religious experience. Out of physical precedents there appear biological, then psychological, then spiritual consequences. Matter gives birth to spirit.

Religion valuing abundant life

Religions arise to rejoice in, wonder over, protect, reform, and regenerate, that is, to save this gift of life, to which humans are intensely bound. The life "information," in contrast to matter and energy, is not inevitably conserved, but rather is inevitably lost in death, unless life is regenerated. If anything is of abiding value on Earth, surely it is the life incarnate in human beings. From the dawn of religious impulses in the only animal capable of such reflection, this vitality has been experienced as sacred. Such experience has often been fragmentary and confused, as has every other form of knowledge that humans have struggled to gain, but at its core the insight developed that religion was about life in its abundance.

Classical monotheism claims—to take the Hebrew form of it—that the divine Spirit or Wind (Greek: *pneuma*) breathes the breath of life into earth and animates it to generate swarms of living beings (Gen. 2.7). Eastern forms can be significantly different: *maya* spun over Brahman, or *samsara* over *sunyata,* but they too detect the sacred in, with, and under the profuse phenomena. Some have opposed as seemingly too self-centered the idea that religions are about fertility. But the fertility hypothesis is quite right in this respect: Humans reside on a fertile Earth.

In that sense, the fact that religious conviction cherishes and conserves this fertility is no reason to think religion suspect; to the contrary, it is reason to think it profound. Perhaps the animal in which such faith emerges, *Homo sapiens,* is coping now because it is detecting that there is a divine will for life to continue. At this point, we pass from supposing that biology can explain religion (as a survival myth) to needing religion to explain biology (how to evaluate this genesis in natural history). Earthen fecundity is hard fact and difficult to explain without some sort of generative principles before which many persons incline to become religious.

Biological value and a value-free nature?

The question of value in biology is paradoxical, both in biological science and in biological phenomena in nature. On the one hand, science thinks of itself as being value-free and as describing a natural world that also is value-free. There is no value without an experiencing valuer, just as there are no thoughts without a thinker, no targets without an aimer. Valuing is "felt preferring" by human choosers. Values can be instrumental or intrinsic; domains of value are economic, moral, legal, aesthetic (including etiquette), cognitive (including science), and religious. Human kinship with the higher animals does extend some of these values to those sentient enough to suffer pains and pleasures. But an event that involves no felt preferences cannot be an event of value or disvalue. Such nature just *is,* devoid of dimensions of value.

Values are, in the usual psychological account, deeply felt and considered, bringing humans back into the main focus. Milton Rokeach defines value: "I consider a value to be a type of belief, centrally located within one's belief system, about how one ought or ought not to behave, or about some end-state of existence worth or not worth obtaining" (p. 124). Values have to be thought about, chosen from among options, persistently held, and they have to satisfy felt preferences. Such values are at the roots of religion.

But this is not adequate biologically. Indeed, by this account, there are no values present in any plants, nor in most animals, which are incapable of such capacities. The paradox arises now, however, because value of another sort is perfused through biology: survival value. An organism lives successfully on the basis of adaptive traits, even if the organism is not a sentient valuer.

So it seems biology is not value-free at all for it is difficult to dissociate the idea of value from natural selection. Every organism has a good-of-its-kind; it defends its own kind as a good kind. A genome encodes what has been discovered to be of value to that form of life. Despite value-free science, value generated and conserved is the first fact of natural history.

Turning to more systematic trends in evolutionary history, biologists are often divided over whether this generation of diversity and complexity is inevitable, probable, contingent, or mixedly all three. Biologists since Charles Darwin (1809–1882) generally dislike the idea of progress or teleology in evolutionary history, though most biologists acknowledge that the evolving Earth did result in increases of both diversity and complexity. Many hold that some systemic tendencies best explain this, even if Darwinism is uncertain about such directions of development.

Within this perspective, humans are not so much lighting up value in an otherwise valueless world as they are psychologically joining an ongoing natural history in which there is value wherever there is positive creativity.

Religions and survival value

Humans evolve with unique traits, especially their dispositions to behave ethically and to be religious. Continuing with Darwinian biology, the only readily available explanation is that these traits convey greater survival value. Most biologists favor the idea of selection at the individual level; if they are right, both ethical action and religious practice must increase the reproductive fitness of individuals who embody these values. But individuals live in communities—intimately in family, where reproductive success is critical, locally in tribes, and regionally in states. Those tribes whose people share religious values usually out-compete other tribes. Religion is reciprocating self-interest, enlarged and enlightened into communities as more fundamental survival units. This account has precedents in the thought of sociologist Émile Durkheim (1858–1917).

Advocates of religion will welcome the survival value of religious beliefs and ethical practices. Abraham was promised numerous descendants, and they became a great nation; the commandments were given to keep Israel, through love and justice, inhabiting the promised land for many generations. But advocates of religion will also resist the idea that religion is nothing but a coping myth, discounting any truth value. Rather, as noted above, the Earth has been perennially prolific. Religion repeatedly arises to encounter this heritage and to insure life's regeneration. Such regeneration includes not only biological survival but requires redemption, the repair of a brokenness in human life. Such salvation is of everlasting value.

This has involved families, tribes, peoples, and nations. The major world faiths, however, have also become universal, evangelizing unrelated others. This proves difficult to explain under the biological account, since such missionary concern conveys no preferential survival advantage on the proselytizers. Rather others are more altruistically valued, a conviction also recently enshrined in universal human rights.

At the metaphysical level, it will be claimed, science neither describes nor evaluates the full genesis of value adequately. Religion is about the finding, creating, saving, and redeeming of such persisting sacred value in the world. In this sense, whatever the quarrels between religion and biology, there is nothing ungodly about a world in which values persist in the midst of their perpetual perishing, or one in which such values, through religious activity, become widely shared. That is as near as earthlings can come to an ultimate concern; that is where, on Earth, the ultimate might be incarnate.

See also BIOLOGICAL DIVERSITY

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RELIGION, THEORIES OF

The theoretical study of religion emerged in the eighteenth century. Like the concept of religion itself, it is the product of, among other influences, the Age of Exploration and Empire (fifteenth and sixteenth centuries), the Protestant Reformation (sixteenth century), and the Augustan Age (eighteenth century). In *The Meaning and End of Religion* (1962), Wilfred Cantwell Smith documents how the premodern etymological antecedents of the modern word *religion* (e.g., Latin *religio*) generally mean something like "the pious Christian rites of worship," not what the modern word means. The practice of translating the premodern terms as *religion,* therefore, often misleads. Non-Western cultures, furthermore, did not have terms with anything like the same connotations or semantic scope.

In premodern Europe, the known religious horizon consisted of (1) the mythology of ancient

Greek and Roman pagans, (2) Jews, (3) Muslims, and (4) Christians. These four could be arranged in a unified narrative by any of the three latter groups. Christians, for instance, could view Jews as stiff-necked people who refused to accept the gospel, and Muslims as schismatics who split Christ's Church. In his poem *The Inferno* (c. 1308), Dante Alighieri consigns Mohammed to the circle of hell reserved for "sowers of scandal and schism" (p. 326). Finally, Christians assimilated Greek mythology to biblical history by arguing that the Greek gods were actually demons, that the Greek myths were actually biblical stories about biblical characters but were corrupted through transmission, or that the Greek myths were allegories representing biblical or Christian virtues. Jews and Muslims had their own unifying narratives. Indeed, the Qur'an itself carefully positions Jews and Christians in relation to Islam. It claims to confirm, continue, correct, and complete earlier revelation.

This comparatively coherent religious horizon eventually collapsed under the growing pressure exerted by European expansion. The Age of Exploration and Empire increased European contact with non-European cultures and non-Western religions. The reports of seafarers about exotic beliefs and practices introduced ethnographic data that could not easily be incorporated into the narratives of premodern Europe. This new cosmopolitanism eroded some of the inevitability clothing Western forms of theism. Renewed attention to, and esteem for, ancient authors (e.g., Lucretius and Cicero) during the Augustan Age, moreover, supplied sources for naturalistic explanations of religion, critique of ritual, and materialistic cosmologies.

Most importantly, perhaps, the Protestant Reformation shattered the relative uniformity of religious thought and culture in Christian Europe. It produced different and warring "religions" (i.e., conceptions of piety and worship), justified by competing criteria of religious authority. This impasse made necessary a neutral stance for assessing religious claims. Only a standpoint that abstracts from contested religious criteria could resolve such a dispute. In the service of religious polemic, early modern thinkers devised canons of inquiry and argument that were independent of religious presuppositions. In order better to conduct religious debate, early modern thinkers secularized inquiry. Conceived by Jansenists to defend their theology against papal condemnation, modern probability theory, for example, both rendered religious presuppositions optional, and facilitated modern science (Stout, 1981). The social discord in which the Reformation culminated made it necessary, furthermore, to privatize religion, to push it out of public affairs for the sake of peace. Religion came to be viewed as a discreet domain of culture, distinct from morality, and ranged alongside law, science, politics, and art. The general term *religion* reflects this differentiation. The Reformation made possible a nonreligious position from which to reflect critically on religion, conceived as a general category identifying one aspect of human intellectual, emotional, and social life.

The emergent theoretical study of religion had its inception in apologetics and polemics. Religionists of one persuasion or another sought out the origin of religion to defend their view from competing religious accounts or irreligious explanations. The bloodshed caused by religious violence and the growing explanatory power of science led others to adopt a nonreligious stance to try to explain religion in nonreligious terms, often with the intention of hastening its supposed demise. Though the polemical inspiration for theories of religion has receded in many quarters, one can nevertheless profitably make a heuristic distinction between humanistic theories of religion and religious theories of religion. Humanistic theories explain religion in terms of the humans who create or subscribe to them. Religious theories explain religion in terms of a religious object, entity, force, or ultimate reality.

This distinction provides only a provisional orientation because humanistic theories can be given religious significance. Ludwig Feuerbach, for instance, argued in *The Essence of Christianity* (1841) that humans unconsciously project the essential characteristics of the human species outside themselves and reify them in the form of a divine being. He insisted that humanity must overcome its self-induced self-alienation by self-consciously restoring its nature to itself. To this extent, Feuerbach's theory is humanistic. Feuerbach complicates matters, however, by insisting that theological statements predicating attributes of God must be inverted. If God is conceived as love, for example, humanity must come to see that love, as an essential component of human nature, is divine. Some read *The Essence of Christianity* as a theological text because they view Feuerbach as collapsing the distinction between a humanistic theory and a religious theory. They see him both explaining religion in terms of the humans who create it, and treating humanity as a religious entity. On this interpretation, Feuerbach's humanistic theory has religious inspiration; it articulates a religious naturalism. Eugene d'Aquili and Andrew Newberg present another case where the distinction between humanistic and religious theories breaks down. In *The Mystical Mind* (1999) they provide models of brain function to explain mystical experience, myth, and ritual. They explicitly aver that their models explain the origin of religion. Yet, they believe this humanistic theory culminates in what they call *neurotheology,* a "megatheology" whose content could be adopted by most of the world's major religions.

Early humanism

David Hume's *The Natural History of Religion* (1757) is the most influential eighteenth-century humanistic theory of religion. In composing a "natural history" of religion, Hume brings religious phenomena within the purview of science. As part of his larger project to create a science of human nature, Hume seeks both to isolate the causes of religion in human nature and to identify the consequences of religion in light of human nature. Not only does Hume consider religion a fit object for scientific investigation, he also theorizes that religion arises in the absence of science. In his pithy phrase, "Ignorance is the mother of devotion" (p. 75). Religion, Hume believes, fills the void when humans lack the aptitude for better founded explanatory principles.

Hume rejects the theological anthropology of his forebears' Calvinism wherein God endows humans with an innate religious sense. In Hume's naturalistic anthropology, religious principles are derivative. They are not an "original instinct or primary impression of nature," like self-love, sexual drive, or love of progeny (p. 21). These latter are all universal, he claims, and have a "precise determinate object," whereas religion is not universal and is not uniform in its "ideas." In this last judgment Hume attends to the extraordinary diversity of religious beliefs. Despite this diversity, he claims, all particular religious phenomena coincide in "the belief of invisible, intelligent power" (p. 21).

If religion itself is not universal, it is, nevertheless, a response to universal feelings. Concern about the "various and contrary events of human life" elicits hopes and fears whose object are the unknown causes of those events (p. 28). Because they need "to form some particular and distinct idea" of the causes and because science "exceeds" their comprehension, "the ignorant multitude" allow the imagination to clothe the unknown causes with human features (p. 29). Hume posits a natural propensity in humans to "conceive all beings like themselves, and to transfer to every object, those qualities, with which they are familiarly acquainted, and of which they are intimately conscious" (p. 29). A French admirer of Hume's theory, Baron d'Holbach, coined the term *anthropomorphism* to capture the tendency Hume describes. Humans, Hume argues, anthropomorphize the unknown causes behind significant events and, thereby, create gods. Anthropomorphizing the unknown causes not only renders them more familiar and comprehensible, but also furnishes the possibility of gaining their favor "by gifts and entreaties, by prayers and sacrifices" to control future events (p. 47).

Hume believed that these two facets of anthropomorphism, that it provides both familiarity (explanation) and the possibility of gaining favor (control), result in opposed tendencies in religion. The need for familiarity and concrete, even sensible, representations of unknown causes explains idols, polytheism, and mythology. The need to gain favor, on the other hand, leads to the obsequious pursuit of ever more exalted terms of praise (and abject means of self-abasement), culminating in iconoclasm, monotheism, and an insistence on mystery. Blatant contradictions in theologies of all types manifest the tension between these needs. The two tendencies produce contrary movements, furthermore, and initiate a continuous "flux and reflux" between polytheism and monotheism. Although Hume believes that both polytheism and monotheism compromise and distort natural human virtue, he believes that monotheism engenders intolerance and exhibits a greater proneness to enormities.

Religious feelings

Hume's theory explains religion in intellectual terms: as an account of the unknown causes at work in the natural and social worlds. An enterprise fundamentally concerned with explanation, prediction, and control, religion, on Hume's view, directly competes with science. Later, Victorian anthropologists like Edward Tyler, James Frazer, and Herbert Spencer likewise adopt a fundamentally intellectualist explanation of religion. They too see religion in conflict with science. As early as 1799, however, an alternative explanation of religion emerges. Unwilling to declare religion obsolete, Friedrich Schleiermacher argues that it constitutes an autonomous domain distinct from science. Religion, he claims in *On Religion: Speeches to its Cultured Despisers* (1799), consists in "the sensibility and taste for the infinite" within finite experience (p. 103). This religious feeling is independent of, and prior to, all thought or belief, though it naturally finds expression in language. The growth of science need not, therefore, conflict with religion because beliefs and judgments are essentially foreign to religion.

Schleiermacher's religious approach to religion influenced later theory as much as Hume's humanistic one. The nineteenth-century German scholar, Max Muller, for instance, theorizes that religion begins in perceptions of the infinite glimpsed in awesome natural phenomena like the sun. Through a "disease of language," the names for the powerful natural phenomena became misconstrued and taken to be the names of superhuman beings. Myths nevertheless metaphorically express the experience of the infinite. In the mid-twentieth century Mircea Eliade interpreted religious symbolism in light of what he called *hierophanies,* the religious experiences wherein one perceives a mode of the transcendent, wholly other "sacred" in a mundane object. In various ways "*homo religiosus*" builds different myths, rites, and beliefs out from the universal symbols.

William James also holds that religious feelings are primary and the explanation of religion. In *The Varieties of Religious Experience* (1902), he argues that various inarticulate feelings of the presence or reality of an unseen something more that is congruent with human interests explain religion. Unlike Schleiermacher, James admits that religious beliefs can conflict with science, but religious beliefs are merely secondary interpretations of religious feeling. Ultimately, he ventures the humanistic hypothesis that the subconscious explains the experiences he describes, but he countenances religious theory by allowing that a religious reality could work through the subconscious. The attempt to safeguard religion from science by maintaining the primacy of feeling—the approach shared by Schleiermacher, Muller, Eliade, and James—runs aground on the fact that religious feelings are not in truth independent of, and prior to, religious beliefs. As Wayne Proudfoot makes evident in *Religious Experience* (1985), religious feelings are constituted by the subject's implicit commitment to a religious explanation of their cause and a religious description of their object. This commitment belies the alleged priority of religious feeling to religious belief.

Society and symbolism

Emile Durkheim conceives his humanistic theory of religion in self-conscious opposition to intellectualist theories of religion. In *The Elementary Forms of Religious Life* (1912) he insists that the generative source of religion cannot simply be ignorance. Otherwise, religion would have disappeared long ago under the pressure of massive disconfirmation because religious beliefs are "barely more than a fabric of errors" (p. 227). Durkheim proposes to explain the persistence of religion (its "ever-present causes") despite the errors it contains (p. 7).

An explanation of religion must, Durkheim argues, recognize that religion is a social fact. Previous theorists grounded their explanations in anthropology, or a theory of the person. One cannot explain social facts in this way, he claims, because societies, though composed of individuals, exhibit laws and properties of their own. Social facts place constraints on individuals and can contribute to explanations of individual psychology. Individual psychology, however, cannot explain a social fact. One should ground explanations of social facts in sociology, or a theory of society. To try to explain religion through a theory of the person entirely misses the social dynamics creating this social fact.

Durkheim grossly overstates the gulf between the social and individual levels of explanation, and even violates his own methodological prescriptions when he appeals to individual psychology in his theory of religion. Nevertheless, he offers a salutary corrective. Hume exemplifies the sort of theory about which Durkheim complained. Despite Hume's interest in the social consequences of religion, his theory of the origin of religion completely neglects social considerations. It almost seems, on Hume's view, as if each individual concocts religion independently. Schleiermacher and James also flout the proper order of explanation. Religion, as a social fact, can help explain the individual's religious feelings better than the individual's religious feelings can explain religion.

Whereas Hume deems belief in invisible, human-like beings to be the hallmark of religion, Durkheim argues that the category of religion includes systems without spiritual beings (or, at least, systems like Buddhism, where spiritual beings possess, he claims, only minor importance). To characterize religion most generally, he introduces a notion that influenced Eliade and his followers, and that eventually succumbed to ethnographic counterexamples. Religion, Durkheim claims, universally entails an absolute distinction between the sacred, "things set apart and forbidden," and the profane (pp. 44). A religion is a shared system of beliefs and practices concerning sacred things that unites a community. For Durkheim community is intrinsic to the idea of religion. This definition, based on the "readily visible outward features" of religion, bears a symmetrical relation to Durkheim's hypothesis concerning its "deep and truly explanatory elements" (p. 21). Inverting his definition of religion, Durkheim ultimately claims that the uniting of the community explains the beliefs and practices about sacred things.

Durkheim believes that the key to explaining religion is a consideration of the individual's relationship to society. The individual depends on society for his or her well-being, yet society demands service from the individual and frequently requires that the individual set aside his or her own interests and inclinations. Society subjects individuals to restraints and privations, but social interaction also fosters courage and confidence. Durkheim argues that the members of a society objectify and project outside their minds the feelings that the social collectivity inspires in them. They feel acted on by a mighty moral force to which they are subject, and, not surprisingly, they imagine it external to them. They fix the feelings on some object, which thereby becomes sacred. Moments of what Durkheim calls "collective effervescence," when the social group physically gathers and the individual feels uplifted and fortified by the crowd, are especially powerful, Durkheim claims, in creating religious ideas and the sacred. Although Durkheim relies on irremediably faulty ethnography and untenable assumptions about the simplicity of "primitive" societies, his interpretation of Australian religion well illustrates his general theory. The Australian totem, he reports, stands both as the emblem of the clan (i.e., the society) and the emblem of sacred power. The sacred power, he concludes, derives from the clan itself.

Two features of Durkheim's theory influenced later twentieth-century theories profoundly. First, Durkheim argues that religious beliefs and rites, the beliefs and practices related to sacred things, symbolize society and social relations. He claims that "religion is first and foremost a system of ideas by means of which individuals imagine the society of which they are members and the obscure yet intimate relations they have with it" (p. 227). Although the believer understands them literally, religious beliefs and practices are fundamentally not attempts at explanation, prediction, and control. Rather, they are metaphorical expressions of social realities. Taking inspiration from Durkheim's injunction that "we must know how to reach beneath the symbol to grasp the reality it represents and that gives the symbol its true meaning" because the "most bizarre or barbarous rites and the strangest myths translate some human need and some aspect of life, whether social or individual," many twentieth-century scholars interpret religious beliefs primarily as symbolic expressions of existential concerns (p. 2). Others, like Mary Douglas and Edmund Leach, who follow even more closely in Durkheim's footsteps, have documented rich correlations between social arrangements and religious representations.

Second, Durkheim supplements his explanation of the origin of religion with a functional explanation of its persistence. Prevalent in biology, functional explanations explain something by its function, or what it does. In the social sciences they explain an institution or behavior in terms of its unintended, beneficial effects. Durkheim argues that religion persists because it satisfies social needs. Society requires a periodic strengthening of the social bond through communal activity that reinforces collective feelings and ideas. Worship, undertaken to maintain the relationship between the individual and the sacred, actually maintains the relationship between the individual and the reality behind the sacred—society. Rituals, meant to strengthen society's relationship to the sacred, strengthen society. That religion fulfils this social function explains, for Durkheim, how it persists despite its errors. Many twentieth-century anthropologists and sociologists adopt functionalism as an explanatory paradigm, but employ it uncritically. Sometimes they naïvely assume that extant religious beliefs or practices must serve some beneficial purpose. Sometimes they heedlessly suppose that the (putative) benefits maintain the beliefs or practices. Not everything that exists, of course, serves a beneficial purpose (some things work to the detriment of individuals and societies) and not everything that has beneficial effects exists for the sake of its effects.

In *Ulysses and the Sirens* (1984) Jon Elster provides the most penetrating analysis of the logic and the pitfalls of functional explanation. He argues that simply demonstrating that unintended, beneficial effects result from the presence of an institution or behavior in a society does not suffice to explain the presence of the institution or the behavior. To explain an institution or behavior's presence by its effects, one must also identify a feedback loop "whereby the effect maintains its cause" (p. 32). In biology, natural selection provides the feedback loop whereby the effect of an adaptation explains its presence in a population. Elster remarks that virtually all social scientists who invoke functional explanations fail to specify a comparable feedback loop. Durkheim's functional explanation of religion arguably does include a feedback loop: The effects of religious rites (strengthened social bonds) maintain their cause (religion) precisely because social bonds produce religion. Elster, nevertheless, rightly criticizes the all too frequent assumption in social scientific theory that unintended beneficial effects provide sufficient explanation for their cause.

Hume *redivivus*

Despite Durkheim's enormous influence over subsequent social scientific theory of religion, some late twentieth-century theory sustains themes advanced by Hume in the eighteenth century. Robin Horton, for example, in a series of essays spanning thirty years (and collected in 1993) argues for an intellectualist explanation of religion. While allowing that religious beliefs can reflect social preoccupations, he rejects symbolic understandings of religion because the subjects of his fieldwork in Africa construe their religious beliefs literally. The motivation to interpret religious beliefs symbolically derives, he argues, from liberal scruples about attributing massive error to so-called primitives. Horton finds this liberal attitude patronizing. Taken literally, religion, like science, represents an attempt to explain, predict, and control the environment. Unlike science, however, which employs impersonal processes and entities as its explanatory idiom, religion employs personal forces and entities. It represents "an extension of the field of people's social relationships beyond the confines of purely human society," an extension "in which the human beings involved see themselves in a dependent position *vis-à-vis* their non-human alters" (pp. 31–32).

Though Horton revives both intellectualism and a variation of Hume's definition of religion, he repudiates the sort of distasteful elitism Hume epitomizes and remedies Hume's neglect of the social factors causing religion. He argues that societies with relatively stable patterns of social organization and relatively poor means of technological control draw on social analogies in constructing their theories because for them the social world represents predictability. Rapidly changing societies with good technological control, on the other hand, draw their analogies from the natural and artificial realms, which to them seem most predictable. Horton maintains that in addition to the use of a "personal idiom" to explain, predict, and control events, humans enter into "communion" relationships—personal relationships viewed as ends in themselves—with the personal entities postulated by religion. Religion-as-theory and religion-as-communion represent two poles or aspects of religion with varying relative salience depending on circumstance. In the modern West science has largely replaced the theoretical role for religion, granting communion greater prominence. This fact, he argues, helps explain the tendency of Western scholars to dismiss intellectualist explanations of religion.

In offering a sociological explanation of the personal beings that define religion, Horton departs from Hume. Stewart Guthrie, on the contrary, adheres to Hume's anthropological approach. In *Faces in the Clouds* (1993) Guthrie adduces copious evidence to suggest a propensity in human nature to anthropomorphize the world. Humans must constantly draw implicit or explicit explanatory conclusions about their surroundings. Guthrie claims that over the course of human evolution, the importance of other humans to human existence selected for traits that facilitate the detection of human agency in ambiguous or uncertain circumstances. A well-developed cognitive predisposition to perceive agents will inevitably produce erroneous results. Religion, Guthrie argues, represents one such result. He characterizes religion as a system of partial anthropomorphism (i.e., gods are only human-like, they are not human *simpliciter*) centered on communication with human-like beings through symbolic action. Science as an institution, by contrast, has historically resisted the tendency to anthropomorphize.

In *Religion Explained* (2001), Pascal Boyer supplies a complementary cognitive theory that likewise characterizes religion as essentially concerned with person-like beings and explains it as a by-product of evolved mental dispositions. From cognitive psychology Boyer adopts the conclusion that humans display cognitive biases that predispose the mind to attend to certain kinds of information, to classify it in specific ways, and to draw certain sorts of conclusions about it. The mind has biases toward a few "ontological categories" (e.g., inanimate objects, animate objects, and agents) that activate specialized "inference systems" (e.g., intuitive physics, intuitive biology, and intuitive psychology). These mental subsystems produce a set of intuitive default expectations concerning members of the category. Boyer contends that supernatural concepts preserve most intuitive expectations, but conspicuously violate a few (e.g., invulnerable organisms or percipient artifacts). These cognitively interesting concepts gain salience from their relative counterintuitiveness, and Boyer provides experimental evidence to show that they are more memorable than intuitive ones.

Specifically religious concepts (as opposed to folklore, myths, etc.) are those supernatural concepts that are "serious" and arouse strong emotions. They gain this additional salience from their "aggregate relevance" to important social and moral processes. Religious concepts concern agents who counterintuitively have full access to information pertinent to social interaction. Concepts involving "full-access strategic agents" gain plausibility and significance from the role they can play in moral reasoning, their congruity with human intuitions about the causes of misfortune, and their capacity to explain the social effects created in ritual. Religion does not produce morality, intuitions about misfortune, or ritual. Rather, the latter simply make some supernatural concepts—the one's concerning full access strategic agents—more relevant.

Though Boyer is critical of intellectualist explanations, both Guthrie and Boyer share Hume's view that religion does not represent "an original instinct or primary impression" in human nature. Like Hume, they believe that religion derives from more fundamental human propensities and predispositions. Religion, they contend, is a by-product of evolved cognitive biases. This approach enjoys considerable advantages. They do not need to show that religion itself confers an evolutionary advantage, nor to delineate a feedback loop independent of natural selection.

Marx and Freud

Sigmund Freud (1856–1939) and Karl Marx (1818–1883) both authored prominent humanistic theories of religion with scientific or quasi-scientific pretensions. Marx endorses Feuerbach's view of religion as alienation and projection, but argues that religion, or alienated consciousness, is only an epiphenomenal reflection of a more basic dehumanizing alienation at the level of social and economic organization. Religion reinforces prevailing social and economic arrangements by both consoling the oppressed and justifying their oppression. Freud's "psychoanalytic" theory explains religion as both the delusional fulfillment of powerful wishes for a protector, and as a symbolic enactment of ambivalence about the father. He describes a primal crime in which jealous sons kill and devour their father. Religions are attempts to allay guilt by deferred obedience to the father. Freud equivocates about the historicity of this oedipal conflict. Sometimes he portrays the primal crime as an historical phylogenetic truth. Sometimes he treats it purely as an illustration of a universal psychological conflict.

Detractors have labeled both Marx and Freud pseudo-scientific. The extraordinary plasticity of their interpretive principles renders their systems virtually invulnerable to counter-evidence. Sometimes they both also explain away and stigmatize objections, rather than meeting them. These features, together with the all-encompassing nature of their theories and the reverence accorded to the founders and the founding texts, leads some critics to liken Marxism and psychoanalysis to religions.

See also FREUD, SIGMUND; HUME, DAVID; MYSTICISM; NEUROTHEOLOGY; SOCIOLOGY

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MATTHEW C. BAGGER

RELIGIOUS EXPERIENCE

See EXPERIENCE, RELIGIOUS: COGNITIVE AND NEUROPHYSIOLOGICAL APSECTS; EXPERIENCE, RELIGIOUS: PHILOSOPHICAL ASPECTS

REPRODUCTIVE TECHNOLOGY

The field of assisted reproduction, or reproductive technology (often called ART), dates to the birth of the first "test tube baby," Louise Brown, in England in 1978. The term *assisted reproduction* is used to indicate the conception of children by means of technology designed to assist the fertility efforts of couples or individuals who might not be able to conceive children without technological assistance.

In vitro fertilization

In vitro fertilization (IVF) is the process by which a woman's ovaries are artificially stimulated with fertility drugs. The drugs are injected into the woman, whose eggs, released from the ovaries, will be stimulated to develop, grow, and mature with the aid of the administered medications. This process, also known as *hyperstimulation,* is physically demanding and carries some risks for the woman whose eggs will be retrieved. The mature eggs are retrieved using a needle inserted intravaginally and guided by ultrasound technology, requiring only a local anesthetic. The older technique of administering general anesthesia and aspirating the woman's eggs through laparoscopy is used less often.

After retrieval, each egg is cultured in a separate laboratory dish and combined with sperm from the woman's partner or from a donor; when the sperm penetrate the egg, fertilization results and IVF has occurred. This happens in an incubator under highly controlled laboratory conditions that mimic the internal body environment. As the fertilized eggs grow and divide, early embryos develop. Technological advances have made it possible to allow the embryos to grow in culture for up to six days, at which point the blastocyst is formed. A blastocyst is often referred to as a *pre-embryo* because it has yet to implant itself in the uterine wall; after implantation it will become a developing embryo. Allowing pre-embryos to develop to the blastocyst stage, in vitro, enables scientists to select those embryos for implantation that are deemed to have the highest chance for a resulting pregnancy, which is the goal of the process.

In order to enhance the chances of pregnancy, it is standard procedure to transfer several embryos back into the uterus (bypassing the fallopian tubes). Consequently, although birth rates are relatively low (ten to thirty percent by most estimates), in the early years of IVF the rate of multiple births was often comparatively high. Over the last decade, in part due to the freezing of embryos (cryopreservation), scientists are able to select fewer embryos for transfer at one time, based on the health and quality of the early embryos in culture. Thus the odds of a woman having a multiple pregnancy are reduced. IVF was performed successfully for the first time in the United States at the Jones Institute for Reproductive Medicine in Norfolk, Virginia.

Blastocyst transfer

Blastocyst transfer, or embryo transfer, is the process by which the pre-embryo is transferred from the laboratory culture dish to the woman's uterus via a tiny hollow needle. Since a fertilized egg subdivides into cells over time (fertilization is a process that takes between twenty-four and forty-eight hours after the sperm penetrates egg), it has been proven to be useful to maintain the process in culture until the fertilized egg has reached cell division of between four and sixteen cells (five to six days is optimal). The transfer of the blastocyst or pre-embryo at this stage then increases the chances of survival in utero and decreases the chances of abnormal or defective embryos being implanted. Developing embryos that do not survive through the blastocyst stage have been found to have chromosomal deficiencies that are not optimal for healthy pregnancies.

Other technologies

Other reproductive technologies related to IVF include *intracytoplasmic sperm injection, preimplantation genetic diagnosis, gamete intrafallopian transfer,* and *zygote intrafallopian transfer. Somatic cell nuclear transfer,* a developing and controversial technology, is associated with human cloning. Each of these techniques makes use of the basic process of IVF but refines the process in ways that are specific to one or more obstacles to fertility.

Intracytoplasmic sperm injection. (ICSI) is a technique developed in 1992 that is used primarily to assist in male factor infertility cases where sperm count is low or nonexistent. In this procedure, sperm are individually isolated by means of micromanipulation and are then individually inserted into the cytoplasm of the retrieved egg in a culture dish. It is possible to combine ICSI with Microsurgical Epididymal Sperm Aspiration (MESA) and Testicular Sperm Extraction (TESE). In MESA, sperm are retrieved from the part of the testes where they mature and are stored; then ICSI is used for the fertilization process. In TESE, the testes are biopsied so that sperm can be obtained from the testicular tissue directly; then ICSI is used to fertilize the sperm.

Pre-implantation genetic diagnosis. (PGD) allows scientists to screen embryos prior to implantation to check for genetic diseases and defects. The technique combines ICSI with IVF and blastocyst transfer. The developing pre-embryos are allowed to grow in culture to the six-to-eight cell stage, at which point one or two cells are removed and biopsied to check for chromosomal abnormalities or single gene defects by analyzing the DNA. Those embryos found to contain chromosomal abnormalities or gene defects are not transferred to the uterus, and scientists are able to select "normal" embryos for transfer with the goal of a pregnancy and birth free from disease. Specifically, fertility clinics using PGD are able to test for single gene defects such as, for example, cystic fibrosis, Tay-Sachs disease, thalassemia, sickle cell anemia, x-linked diseases such as hemophilia and muscular dystrophy, and spinal muscular atrophy. PGD can also test for abnormal numbers of specific chromosomes and associated diseases such as Trisomy 21/Down syndrome, Turner's syndrome, and other such conditions.

PGD, combined with IVF, has been used successfully in several cases, some of which are ethically controversial. On August 29, 2000, Adam Nash was born as a result of this procedure. Adam's parents chose to use PGD to make sure that, in vitro, only embryos found not to contain Fanconi's anemia disease would be transferred to the uterus of Adam's mother. Adam's older sister, Molly, had Fanconi's anemia, a rare bone marrow disease, and her only hope of a cure was a bone marrow transfer from an exact donor match. After Adam was born, cells were collected from his umbilical cord and transplanted into Molly's circulatory system.

The ethical controversy surrounding the Nash case centered on two issues: (1) whether it is permissible to create a child as a means for assisting someone else (in this case, his sister); and (2) whether it is ethical to allow screening and selection of traits and conditions prenatally. The second issue raises the specter of what has colloquially been referred to as *designer babies*. Ethicists tend to be wary of the move to use technology prenatally to select out various traits, although the use of this technology to avoid conceiving a child with a destructive disease such as Tay-Sachs is, for many ethicists, less morally problematic than selecting out, for example, children with Down syndrome. The technique of PGD, combined with continuing advances from the Human Genome Project, raises the theoretical possibility of selecting out embryos for implantation based on traits connected with certain genes. For example, should the genes for homosexuality, intelligence, obesity, or a host of other conditions be clearly identified, it would be possible to select for or against those embryos by means of IVF and PGD.

Gamete intrafallopian transfer. (GIFT) and its related technology, zygote intrafallopian transfer (ZIFT), are technologies that use donor gametes (sperm or egg) combined with IVF to transfer the resulting embryo to the fallopian tubes of the woman who wishes to conceive. Specifically, in GIFT, fertilization occurs in vivo, in the body. ZIFT places already developed zygotes into the fallopian tubes.

When donated gametes are used for this process, donors are usually paid, raising issues about the commodification of reproduction (Holland). Such procedures make it possible for single persons and gay and lesbian couples to have children using assisted reproduction. Selection of donor gametes also raises the issue of eugenics (selective breeding) because it is now widely possible to "shop" for gametes by making up a list of desirable factors and finding them with the help of egg and sperm brokers.

Somatic cell nuclear transfer. (SCNT) is another form of assisted reproduction. This process, famously pioneered on Dolly the sheep and announced in 1997 by Ian Wilmut and his colleagues, has been experimented with in human fertility clinics. In its simplest sense, somatic cell nuclear transfer involves taking an adult somatic cell (not a reproductive cell), removing its nucleus, and transferring the DNA into an enucleated (containing no nucleus) donor egg. The donated egg is then "tricked" into the fertilization process by an electrical (or chemical) stimulation and begins cell division. Theoretically, the cloned embryo would then be implanted in the uterus using IVF techniques. Although several kinds of animals have been cloned, primates have not, and as of mid-2002, there is no public evidence that human cloning has been attempted, though there have been reports that Antinori Severino, an Italian fertility doctor, is engaged in this work.

The American public has been overwhelmingly opposed to the use of SCNT because it raises fears of madmen such as Adolf Hitler cloning armies of an Aryan master race, and other such scenarios. The technology is so difficult that these fears have no grounding in fact; however, it will certainly be possible one day to "clone" a human being via the process described. This type of cloning may be accurately thought of as "delayed twinning," for the cloned child would in fact be the genetic twin of the original donor. It raises some of the same ethical concerns as those raised under PGD, although at this point PGD technology has proven to be safe, while SCNT is not at all safe for use in human reproduction. As such, several ethics advisory boards, including the National Bioethics Advisory Commission (1997) and the California Advisory Committee on Human Cloning (2002), have recommended a moratorium on the use of this technology in humans until such time as it is proven to be safe.

Fertility specialists are also working on nuclear transfer techniques that would make it possible for a woman who wishes to conceive to have the nucleus from one of her unfertilized eggs removed and inserted into an enucleated egg donated by another woman. This is nuclear transfer, but not with a somatic cell. The goal of this procedure, when perfected, will be to assist older woman whose eggs are not ideal become pregnant using the eggs from a younger woman while retaining the DNA from the mother-to-be. One pioneer of this technique is Jamie Grifo at New York University Medical Center (Holt).

Religious responses

Assisted reproduction is now widely used around the world, and especially in the United States, although specific techniques continue to be of concern to ethicists, and religious communities have a variety of perspectives on the matter. The religious institution most clearly opposed to assisted reproduction is the Roman Catholic Church. In its 1987 instruction *Donum Vitae* (Gift of Life), the Catholic Church clearly states: "Through in vitro fertilization and embryo transfer and heterologous artificial insemination, human conception is achieved through the fusion of gametes of at least one donor other than the spouses who are united in marriage. Heterologous artificial fertilization is contrary to the unity of marriage, to the dignity of the spouses, to the vocation proper to parents, and to the child's right to be conceived and brought into the world in marriage and from marriage" (O'Rourke and Boyle, p. 63). Thus the Roman Catholic Church's objection to assisted reproduction is grounded in classical natural law theology that opposes the separation of procreation from the conjugal act of love in marriage. Nevertheless, many Catholics in the United States deviate in practice from their church's official teachings on contraception, abortion, and assisted reproduction.

Moderate and liberal Protestant denominations in the United States, often referred to as *mainline Protestant,* include the American Baptist Church, the Episcopal Church, the Presbyterian Church USA, the United Church of Christ, the United Methodist Church, and the Evangelical Lutheran Church. In general, these denominations emphasize fidelity to Scripture in formulating one's moral response to a situation, as distinct from the emphasis on church doctrine or tradition that one finds in Roman Catholicism. Thus, as Christian Green and Paul Numrich point out in their 2002 book, *Religious Perspectives on Sexuality,* these mainline Protestant denominations, while they have a variety of official responses to reproductive issues, tend to affirm the right of individuals to discern for themselves how to make use of reproductive technologies.

Conservative Protestantism includes the Southern Baptist Convention, the Assemblies of God, the Association of Vineyard Churches, and a variety of independent, evangelical fundamentalist churches. They have in common with mainline Protestants an emphasis on the primary authority of the Bible, but these churches are generally distinguished by an insistence on a literal interpretive framework. Their positions on reproductive matters tend to include an active opposition to abortion, but assisted reproduction has not been much considered in formal church statements. In general, "They tend to approve of methods intended to correct physical problems that cause couples to be infertile, but they disapprove of methods that would violate the sanctity of the marriage bond by using donated sperm and eggs, as well as any method that would tamper with or discard a fertilized embryo" (Green and Numrich, p. 11).

The three branches of Judaism—Orthodox, Conservative, Reform—each have a variety of responses to assisted reproduction and their concerns are relative to the importance each branch places on upholding Jewish law or *halachah*. Assisted reproduction tends to be permitted in most branches of Judaism, although there are more and less problematic forms of reproductive technologies. Those forms of assisted reproduction that make use of the eggs and sperm of the couple trying to conceive are less problematic than those that make use of donor gametes; indeed, in Orthodox Judaism, donor gametes raise concerns of adultery. Surrogacy, too, is permissible for Jews, and there is ancient Biblical precedent for it. Since conception and the raising of children are cornerstones of Judaism, assisted reproduction tends to be viewed as permissible and even a good thing if it results in childbearing. Moreover, since, for example, Tay-Sachs disease is a devastating disease for Ashkenazi Jews, the use of PGD and other forms of assisted reproduction that prevent the birth of Tay-Sachs children has been widely embraced by Judaism. Moreover, therapeutic cloning (using SCNT for obtaining stem cells) has been approved by the Union of Orthodox Jewish Congregations of America and the Rabbinical Council of America, the two largest Orthodox Jewish organizations. It is widely expected that the other branches of Judaism will follow suit (Cooperman, Dorff).

Islam is also characterized by many schools of thought and practice: Sunni Muslims consider themselves followers of Muhammad's tradition; Shiite Muslims, the second-largest branch of Islam, adhere to the authority of the supporters of Ali, Muhammad's son-in-law; Sufi Muslims, the smallest branch, stress mysticism and personal worship. In the United States, many African-Americans have joined the Nation of Islam, which is based on the teaching of Elijah Muhammad. So although there is a wide variety of Islamic expression and values, in general the views of Islam on assisted reproduction are similar to those of Judaism in that most forms of assisted reproduction are permitted, with the caveat that only the eggs and sperm of the married couple are used. Surrogacy, however, is generally not permitted.

See also CHRISTIANITY; CHRISTIANITY, ROMAN CATHOLIC, ISSUES IN SCIENCE AND RELIGION; CLONING; ISLAM; JUDAISM; REPRODUCTIVE TECHNOLOGY

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SUZANNE HOLLAND

REVELATION

Prior to the twentieth century, it was usually assumed that revelation was received in two modes. "Special" revelation represented communication of knowledge about God through supernatural agency. "General" revelation consisted of what could be known of God through either abstract philosophy or reflection on the nature of the universe.

Twentieth-century challenges

In the twentieth century, however, there were strong challenges both to the concept of revelation as disclosure of propositional knowledge and to the validity of a "natural theology" based on general revelation. The work of the Swiss Protestant theologian Karl Barth (1886–1968), in particular, had led, by the middle of the century, to both a new emphasis on the centrality of special revelation for theological thinking and a perspective in which theological propositions represented no more than human reflection on God's historical acts. This emphasis on "revelation in history" had a major influence in making propositional understandings of revelation unfashionable.

This tendency was subsequently reinforced, for some, by instrumentalist understandings of religious language, such as those associated with existentialism, with "linguistic" understandings, and with more specifically postmodernist approaches. As a result, except in neo-orthodox circles, which still looked to Barth for inspiration, the focus for many shifted from historical revelation towards existential criteria and existing religious communities. Despite the ways in which this gap was bridged by the work of people like Yves Congar, on revelation, and of Janet Soskice, on religious language, these perspectives resulted in a widespread belief that theological reflection was essentially unaffected by scientific understanding.

Perspectives from science and religion

The dialogue of science and theology during the second half of the twentieth century was based, in large part, on a reaction to this "independence" thesis, as Ian Barbour called it. The simplistic separation of science and religion that had arisen from seeing the one as based purely on empirical problems, and the other as based purely on special revelation, was strongly challenged. Beginning with the work of Barbour himself, it was increasingly stressed that science itself was more complex in its rationality than was commonly understood, and that there were important parallels between the ways in which religious and scientific languages were employed.

Two factors were characteristic of this phase of the dialogue of science and theology. One was that the dialogue was often seen in apologetic terms, its goal being to vindicate the consonance of scientific and theological worldviews. This consonance was interpreted, however, largely in terms of the way in which both disciplines could be seen as using revisable models of reality. This owed much to Karl Popper's (1902–1994) analysis of the sciences, and manifested little recognition of broader, postfoundationalist perspectives. The other, and related, factor was that theological language was often approached from a perspective that stressed the more conservative aspects of the sort of "critical realism" that had become, among philosophers of science, the dominant understanding of scientific language.

Modifications that might have been made to this position, through an awareness of recent thinking about revelation, were conspicuous by their absence. At the level of epistemology, dissenting voices—such as that of Thomas Torrance—tended to look back to Barthian viewpoints. Only in the last decade of the century were there significant challenges based on new perspectives, which attempted either to modify the realist position in a major way (Christopher Knight), to dispute realism in favor of an emphasis on methodological parallels (Nancey Murphy), or to emphasize the importance of postfoundationalist insights (J. Wentzel van Huyssteen). Despite these challenges, however, the older, quasi-propositional approach remained influential.

One of the more fruitful aspects of this approach was, even for some who were otherwise critical, the attempt to challenge the Barthian rejection of the concept of "natural theology." Few attempted to defend its historical forms—recognizing, for example, that neo-Darwinian understandings had rendered design arguments such as William Paley's (1743–1805) redundant. Nevertheless, although it was acknowledged that no "proof" of God's reality could now be provided, people like John Polkinghorne advocated a "revived and revised natural theology"—persuasive but not logically coercive—based on issues such as the anthropic cosmological principle. Similarly, people like Arthur Peacocke urged the relevance of the concept of inference to the best explanation.

The propositional understandings of revelation implicit in these approaches were, however, further undermined by another issue that took on new importance towards the end of the twentieth century. It was the question of whether, and how, religious faiths other than one's own can be seen as having arisen from God's revelation of himself within different cultures. Keith Ward, in particular, attempted to develop an understanding of revelation that took up the pluralist insights of earlier investigators into the relationship between different faiths.

One of the most comprehensive responses to this issue from within the science and religion debate was that of Christopher Knight, who advocated a pluralist understanding of revelation based on an essentially naturalist understanding of divine action. Using the experiences of the risen Christ as his prime example, Knight explored the psychological basis of revelatory experience to affirm what he called a psychological-referential model of revelatory experience. As Ward's own position indicated, however, Knight's type of naturalism was not the only approach through which a pluralist understanding could be affirmed. A more conservative understanding of divine action can also give rise to a pluralistic position.

It is perhaps in the context of postfoundationalist understandings of rationality that the concept of revelation will most markedly affect the dialogue of science and theology in the near future. J. Wentzel van Huyssteen's approach, for example, is one that assumes, in the views of some, too great a distinction between theological and scientific rationality. Nevertheless, his way of acknowledging crucial areas of overlap provides a challenge to the simplistic distinction between empirical problems and God's revelation, which is often still held to separate science and theology. This acknowledgement is likely to be of considerable influence in an era profoundly influenced by postmodernist perspectives. A more subtle understanding of revelation than is yet common can, arguably, allow the implications of his insights to be fully explored.

See also ANTHROPIC PRINCIPLE; CRITICAL REALISM; DIVINE ACTION; EPISTEMOLOGY; LANGUAGE; NATURAL THEOLOGY; POSTFOUNDATIONALISM; POSTMODERNISM

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RITUAL

Ritual is normally defined as gestures and, often, linguistic actions that follow a preestablished schedule and have a communicative purpose. Anthropologist Roy Rappaport (1926–1997) defined *ritual* as "the performance of more or less invariant sequences of formal acts and utterances not entirely encoded by the performers" (p. 24). According to this minimal definition, rituals occur among animals and human beings. Religious rituals are a subgroup of human rituals. A more specific definition depends on the definition of religion, which normally refers to ultimate values or transempirical beings.

Ritual is related to phenomena such as rite, cult, service, liturgy, ceremony, and feast. *Rite* often designates a single ritual act, *ritual* a series of rites. Quasi-synonyms such as *cult* and *service* designate a subclass of religious rituals. *Liturgy* normally means the spoken part of a service. *Ceremony* designates religious and nonreligious rituals, often with a connotation of something superficial, formal, less important. *Feast* can designate a class of rituals with a connotation of the uncontrolled, chaotic, and a violation of norms.

Ritual is normally understood as being a collective phenomenon. The Scottish scholar W. Robertson Smith (1846–1894) regarded religious rituals as more basic than doctrines or individual convictions, rituals being common for a group and relatively durable, while doctrines and convictions may vary individually and are more vulnerable to changes over time. French philosopher and sociologist Émile Durkheim (1858–1917) regarded rituals as the occasions where the holy is articulated and preserved. Religion, the rational core of which is a society's morals, ideals, and principles, is mediated to the individual participants when they gather together to form a community. The assembly also signifies a rupture with the routines of daily life. Therefore, a certain effervescence, conditioned by group psychological mechanisms, often arises, where the individual participants experience a moment of self-forgetfulness and of collective identity. Hereby the individual's obligation toward common ideals is strengthened; new ideals may also develop more or less spontaneously in such gatherings. All religion, and in fact all social fabric, from the most archaic to the most modern forms, presupposes gatherings with at least a touch of effervescence.

Henri Hubert (1872–1927), Marcel Mauss (1872–1950), and Arnold Van Gennep (1873–1957) described a basic syntagm in three parts for all rituals: first, the participants are drawn out of the profane, daily world; second, the central acts are performed; finally, the participants are reconnected with the profane. Van Gennep pointed out the universal occurrence and significance of rituals of transition and initiation

The effervescence of ritual and its partial violation of norms was elaborated by Roger Caillois (1913–1978) and Georges Bataille (1897–1962), who emphasized the extravagant consumption of values in feasts and offerings. Mircea Eliade (1907–1986) saw ritual as an occasion for the abolition of historical and linear time and for contact with archaic notions of the origin of the world and the regeneration of life. Victor Turner (1920-1983) analyzed the central part of initiation, the phase of *liminality,* as a state where the structures of normal life are suspended, the normal differences between the participants are replaced with a temporary community and brotherhood or sisterhood (a *communitas*), and often the initiates are under strict surveillance of ritual leaders with extensive authority. Typically, the initiates are instructed in the mythic and normative foundation of their society, but alternative understandings of life and norms may also be articulated. Turner has seen tendencies to formations of permanent forms of communitas in, for example, monastic movements and pilgrimages. According to Turner, the fertile chaos of liminality has been the origin of theater and performance.

Walter Burkert (1931–) and René Girard (1923–) both emphasized bloody sacrifice as a central ritual; here a group of human beings mitigates internal aggression by directing it toward a designated animal, which is slaughtered and sometimes eaten. Inspired by ethological studies, Burkert stressed the origin of rituals in the life of animals; rituals are sequences of actions, where an original pragmatic purpose has been replaced by a communicative content. To Burkert, different rituals can have different origins. Girard assumed that rituals of all types have been "generated" by a common original form, which is the spontaneous expulsion of a common adversary, a scapegoat.

The structure “all-against-one,” common in many rituals, is such a remnant of the primeval scene.

To Rappaport, who combines a Durkheimian inspiration with phenomenology of religion, semiotics, theory of speech acts, and evolutionary theory, the ritual is the place where linguistically formulated norms and conventions are made obligatory for a group of human beings; ritual is “the basic human act.” Purely linguistic meaning is conventional and open for misuse (lies) and misunderstanding (Babel). In order to withstand disintegrating tendencies from without or within, every group of human beings must commit its members to a certain amount of consensus and predictability. By their mere participation in a ritual—that is, by their self-submission under its preestablished rules for acts and linguistic utterances—the participants signal that they give up a part of their subjectivity and commit themselves to a common universe of norms and significations, in spite of their own “inner” thoughts and feelings. Therefore ritual typically includes performative, self-committing speech acts. The relative “weight” of ritually mediated meaning is reflected in the fact that ritual demands not only the thoughts and feelings of the participants, but also the presence of their bodies.

At least in Protestant-Christian theology, rituals have been problematic since the age of Enlightenment. Already in the early Reformation, the sacraments, which are key examples of rituals, were interpreted as preaching in other forms. Often rituals have been considered external, figurative, affective, and possibly infantile or archaic, and in any case secondary in relationship to rational theology, which necessarily is formulated in symbolic language, spoken and written. Normally the marginalizing of ritual does not assume the shape of a polemic, which aims at abolishing ritual altogether, but rather a disinclination for a proper reflection on it. On the other hand, rituals are often appreciated by those who want to keep a strong emotional dimension in church services.

See also SEMIOTICS

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ROBOTICS

The term *robot* derives from the Czech word *robota,* which means slavery, drudgery, or compulsory labor. In 1920, the Czech author Karel Čapek (1890-1938) wrote a play entitled *R.U.R.: Rossum's Universal Robots,* where he used *robota* for machine-humans, giving rise to the English word *robot*. The science fiction writer Isaac Asimov coined the term *robotics* as the field of academic study of the construction of robots. This connection to fiction points already to the utopian and eschatological elements in the science of robotics.

Kinds of robots

Basically, one can distinguish between industrial robots and artificial intelligence (AI) robots. Industrial robots are either remote controlled devices or machines that repeat constantly a series of movements, as in a factory. AI robots have some level of intelligence that enables them to react more flexibly and autonomously in their environment. The two kinds of AI robots mirror the two camps within AI. *Classical* AI robots are controlled by a central processor running a specific program. Such robots are used in highly restricted static environments. *Embodied* robots on the other hand are distributed systems interacting with natural worlds. Both technologies have a wide array of applications ranging from household robots, nurses, search and rescue robots, robots used as social agents for global communications, and robots used in ubiquitous computing (intelligent agents hidden in everyday tools such as stereos and coffeemakers).

The understanding of human intelligence in AI robotics mirrors specific theories about humans and their intelligence. In Classical AI, intelligence is understood as information processing. The most important elements of intelligence are learning, knowledge representation, searching, language, and mathematical theorem proving. One of the most well-known applications for this type of intelligence is chess. When applied to robots, this concept makes for very good and reliable machines that act in clear defined, restricted, and unchangeable environments. In natural worlds, however, these robots can navigate only very slowly and cannot deal with rapidly changing surroundings.

Embodied AI understands intelligence as a result of the evolutionary process and thus as the capability to survive. Abstract features such as logic and chess are seen as by-products of the human capability to survive in many different environments. Robots built according to this understanding of intelligence are increasingly autonomous. During the late 1990s, researchers started to build autonomous robots with social features for natural human-robot interfaces, which enlarges the field of possible applications.

Ethical and religious perspectives

Several theological and ethical problems arise in robotics. One argument for the use of robotics in industry and manufacturing is that it liberates humans from tedious work. But robotics also threatens to make many humans superfluous and to eliminate jobs. However, this issue is not specific for robotics but relates to the whole area of technology and will not be explored in this entry. The following ethical and theological problems refer to AI robots only.

Playing God. Often people think that AI researchers do their work out of hubris. AI roboticists who build autonomous creatures are sometimes accused of "playing God." The dangers of such actions are described in myths, including the myth of Prometheus, and the story of Frankenstein in Western culture. The Jewish Kabbalah provides an alternative view in the construction of *golems* (artificial humans made from clay), which is seen as a form of prayer. The *imago dei* (the Biblical statement that God has created humans in God's image) symbolizes the divine creativity in human beings so that whenever people are creative they praise God. In "rebuilding" themselves, people create the most complex being God created, thus praising and celebrating God to the utmost. Many of the founders of AI come from this Jewish tradition and understand their work in that sense.

Anthropomorphization and human uniqueness. If it were possible for researchers to build robots that work like humans, does that mean humans are also some kind of machine? Many people feel threatened by AI products because they seem to undermine human uniqueness. Because most people react more strongly to physical entities, the threat is perceived to be even greater with robots. Instead of just being connected to a computerized entity via a keyboard and screen, people connect with robots in a physical, sensual way, and they have to deal with creatures that share their physical space.

Experiments by Byron Reeves and Cliff Nass have demonstrated the degree to which humans anthropomorphize gadgets that are in some way responsive. Their experiments reveal that anthropomorphization of stereos, cars, or computers is a natural reaction in humans, and it takes a conscious effort for people to *not* react that way to the technical tools with which they interact in daily life. That is, people tend to react to robots as if they were partners, yet this reaction, stemming from innate social mechanisms, triggers fears not just that humans will loose their uniqueness but also that robots may surpass humans and make humans superfluous.

In most cultures, the human understanding of self contains an element of specialness; humans are distinct and cannot be compared with other species. In the Jewish and Christian tradition this sense of specialness has often been based on the *imago dei*. For millennia, people have attempted to identify with empirical human features, such as the humanoid body, human intelligence, or humor. A *relational* interpretation of the *imago dei* seems to have become prevalent. Based on *a relational ontology,* the *imago dei* is a promise of God to start and maintain a relationship with humans. Human uniqueness is then based not on special human capabilities but only on the faith-based statement that God has chosen humans as partners with whom God can interact and who will answer (sometimes).

The fear of losing human uniqueness when researchers are capable of building machines that are as smart as people is thus based on a traditional interpretation of the *imago dei* and can be overcome by this relational understanding of the concept. With this concept in mind, the idea of humans constructing robots as a spiritual enterprise, as depicted in the golem tradition, gains a stronger foundation. Christians may add that just as God is relational in the trinity and in the relation with humans, humans are relational. In building robots, humans create creatures with whom they can interact and who will answer. What is amazing is that even the simplest insect is much more complex and more interactive than any robot the most brilliant engineers have been able to build as of the beginning of the twenty-first century. Building autonomous robots in the image of God's creatures does not therefore make humans arrogant, but rather increasingly modest and admiring of the complexity of God's creation.

See also ARTIFICIAL INTELLIGENCE; CYBERNETICS; CYBORG

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ANNE FOERST

ROMAN CATHOLICISM

See CHRISTIANITY, ROMAN CATHOLIC, ISSUES IN SCIENCE AND RELIGION

S

SACRAMENTAL UNIVERSE

Sacramental universe (SU) is a conception of the universe as sacred, a holy temple wherein divinity and creatures play, co-create, and bestow grace. According to the medieval Christian philosopher Thomas Aquinas, “God has produced a work in which the divine likeness is clearly reflected—the universe itself.” All beings possess intrinsic worth, participating in divine beauty; each being is a “Cosmic Christ” or “Buddha nature,” reflecting divine radiance. German physicist Fritz-Albert Popp’s finding that every atom contains photons underscores this teaching that microcosm as well as macrocosm share in the radiance of SU. Destruction of the ecosystem is a sacrilege against SU. A “universe as machine” ideology denies SU and replaces holy sacrament with blind materialism.

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MATTHEW FOX

SACRAMENTS

From the Latin word *sacramentum,* meaning oath, a sacrament is an outward sign or ritual (*signum*) connected to an invisible reality (*res*). In Christian context, it bears a promise from God for the comfort and encouragement in faith of the believer. Augustine of Hippo (354–430) was among the first of Christian theologians to propose a theory of sacraments, and his proposal has been most influential: “The word [of God] comes to the element and it becomes a sacrament.” Peter Lombard (c.1100–1160) then added the idea of causation to sacramental actions; thus the popular definition in virtually all Christian traditions: A sacrament is a visible sign of an invisible grace of God and causes what it signifies (*efficit quod figurat*).

Whereas Eastern Christianity understands sacraments as primary media for God’s continuing creation of authentic humanity (*theosis,* or divinization, often misunderstood as a qualitative changing process of natural humanity into nonhuman divinity), Western Christianity, because of its understanding of sin as a rupture in the relation between God and humanity, would come to emphasize the assurance of forgiveness through the sacraments. Protestantism would add to this perspective the criterion that a sacrament be clearly mandated by God through Holy Scripture, thus always tying sacraments to God’s word. This definition led to a Protestant narrowing of the number of acts identified as sacraments to two or possibly three (baptism, Eucharist, and penance), though the Council of Florence (1438–1445) fixed the number for Roman Catholicism at seven (baptism, confirmation, Eucharist, penance, extreme unction, ordination, and marriage). Some Protestant perspectives, especially within Radical Protestantism movements, hold that sacraments are more symbolic than actually bearing and effective of divine presence.

Cross-cultural perspectives

Judaism does not have sacraments per se, but the philosophy of time involved in such celebrations as the Passover meal enables the Jewish believer to claim participation in holy historical events, like the deliverance from captivity (Exodus). Islam is deeply suspicious of anything that could be interpreted as an image and therefore idolatrous. Even so, the practice of *salat,* disciplined prayer five times a day, is deeply sacramental. *Salat* is said to mimic the Prophet's mystical experience of receiving prayerfulness as a gift and then with prayer ascending through the heavens to the divine throne. Turning to the East, though Buddhism generally insists on the ephemeral and transitory character of nature, the practice of Tantric *pancamakarapuja* in both Buddhism and Hinduism, as well as in Jainism, places the goddess directly or symbolically (depending upon the sect) within forms of nature. These love feasts, guarded carefully against purely sensualist interpretations, display a deeply embodied sensibility about divine presence, and are echoed in the better known phenomena of ritual river washings. Daoism's belief that all nature is united in the Dao, with concern that the forces of nature be properly directed within one's own body, also suggests a profoundly personalized as well as embodied concept of divine presence. Nevertheless, a formally sacramental character about these examples cannot be claimed, though their consonance is noteworthy.

Sacraments in the science-religion dialogue

The use and theology of sacraments (sacramentology) begs the question of the relation between nature and grace, also known as the question of the relation between nature and supernature or between matter and spirit. Where theologians and scientists may agree that their disciplines are neither merely opposed nor in mutual avoidance, use of sacraments may be the most palpable example of how theology and science might converge, particularly as new theology informed by science proposes integrated or complementary descriptions of *what* happens and *how* in sacramental practice. Christian tradition often has invoked imagery from the natural world metaphorically to commend the value and meaning of sacraments. Still, religion and science are careful not to overemphasize their common grounds. Theologians and scientists are usually wary of conflating their disciplines with one another, and such wariness is hardly more evident than with sacramentology. Thus, Christian theology normally would not advert to the ultimate authority of a scientific explanation, nor would such explanation presume to "prove" the Christian claim.

But religion could and increasingly does explore how the meaning of its dogmatic claims—as with what happens in the Christian Eucharist—might be more illumined in engagement with scientific observation. For example, the quantum physical phenomenon of particle entanglement—wherein the actions of one particle in relation to another have ineluctable influences on all other particles both have encountered—suggests a physical image of the depth and breadth of relationship between all believers initiated in Baptism, which the Eucharist (Holy Communion) is believed to sustain and deepen.

Contemporary sacramentology also, with much help from the sciences, prefers to speak of the sacramental phenomenon in more holistic terms, rather than speaking in a reductionistic way of only the elements and words themselves. Even the most solitary act, like extreme unction, is to be seen, like Baptism and Eucharist, as one around which the whole community of believers is marshaled. Borrowing from evolutionary biology and contemporary sociology, one might say that a sacramental action is an emergent event, irreducible to its parts, that is a unique collective of worshipers and their gifts gathered in dedicated spaces around central rites and forms. As a collective representation in a gathered community of diversity, a sacrament represents something of divine activity, and even of divine character (e.g., God as a community of diversity, as Trinitarian theology suggests).

The collective representation thus both creates and extends the reality it expresses, though it does not understand the creation to be *de novo* as much as it is an incarnation. Sacramental change, then, is not so much a matter of what happens to the material foci of the sacramental act, as it is especially a matter of what happens in the relations to and of all the people gathered into and around the act, and so also to the world brought with them. The language of relations softens categorical distinctions. Perhaps more than analogously, the terminology of phase transitions in scientific description suggests the same point. Indeed, such is the conclusion of much ecumenical conversation, which advances Christian theology well beyond the medieval doctrines of substances and accidents that dominated sacramentology until the mid-twentieth century.

Sacraments are not concerned only with human relations, however. Nor are they conceived to be mere bridges between the evidently natural and the divine. They are believed indeed to be those occasions most expressly where the divine and human intimately relate and wherein the distinction between divine and natural can be ambiguous. Sacraments express a primary conviction that nothing human or natural is alien to God. In no way, however, do sacraments allow simple identification of divinity with the natural, otherwise known as pantheism. They are, according to their traditions, promises of tangible times and places where the divine may be encountered and mediated. Thereby sacraments suggest how God intends divine and natural relation in the rest of the world.

Personal sacramental understanding is a matter of faith's being informed by experience, and perhaps theory, but finally resting in the mystery of God. Science may illuminate for religion something of sacramental meaning, and even suggest modes thereby of God's action in the world. But neither science nor religion could reasonably or dogmatically claim absolute comprehension of the topic of sacraments, related as they are to God, who is by definition ultimately transcendent as well as immanent. There also remains for the believer nurtured by sacraments the significant ethical charge to carry forward and enact the divine will in the natural world. This charge includes the creation and care of a materially and spiritually just and peaceful world. Sacraments, so it would appear with Christianity and analogous activities in most other religions, intend the re-constitution and nurturing of divine/human community.

See also SACRAMENTAL UNIVERSE

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See TRANSMIGRATION; LIBERATION

SCHRÖDINGER'S CAT

Schrödinger's Cat is a famous thought experiment conceived by Austrian physicist Erwin Schrödinger (1887–1961) in 1935 to highlight some of the paradoxes of the quantum picture of the subatomic world if applied to everyday experience. Schrödinger was motivated by a paper on the EPR paradox by Albert Einstein, Boris Podolsky, and Nathan Rosen that had appeared earlier that year. Schrödinger opposed the Copenhagen Interpretation of quantum mechanics developed by physicist Niels Bohr (1885–1951) and others, and Schrödinger regarded his thought experiment as a "ridiculous case" that challenged its rationality.

Quantum theory allows only probabilistic statements to be made about the expected outcome of a measurement or observation. We can predict only the probability of finding an electron in a particular state in the future even if we are in possession of all possible information about its present state. Schrödinger imagined observing a cat in a sealed room along with a Geiger counter sitting beside an occasional source of radioactivity. If the Geiger counter records one of these random radioactive decays then it triggers the release of poisonous gas, which kills the cat. If no radioactive decay occurs, the cat survives. The experiment ends after one hour, when we look in the room to see if the cat is dead or alive. According to the Copenhagen Interpretation of quantum mechanics, Schrödinger claims, before we look into the room the cat is described by a wave function that is some mixture of "dead cat" and "live cat." When and where does the half-dead-half-alive mixed cat state turn into the definite dead cat or live cat state that we discover on looking in the room? Who is the observer who produces the definite state? Is it the cat, the Geiger counter, or the person who looks in the room? How do we interpret the state of cat that is half-dead and half-alive before an observation takes place?

See also COPENHAGEN INTERPRETATION; EPR PARADOX; PARADOX; PHYSICS, QUANTUM

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SCIENCE AND RELIGION

The immediate historical roots of the academic field of "science and religion" lie in the 1960s when major developments in the philosophy of science and the philosophy of religion, new theories and discoveries in the natural sciences, as well as complex shifts in the theological landscape, made possible constructive interaction between often separate or even hostile intellectual communities. Most of the discussion has focused on interaction among the sciences and the diversity of Christian theologies, but this is changing as more and more voices from other religions enter the conversation.

Methods for relating science and religion

Scholars first set out in the 1960s to develop more constructive ways of relating the two areas. Scientist-turned-theologian Ian Barbour provided the initial "bridge" between science and religion in his *Issues in Science and Religion* (1971), drawing on the work of Thomas Kuhn, Michael Polanyi, Stephen Toulmin, Mary Hesse, Frederick Ferré, Norwood Hanson, and others in both the philosophy of science and the philosophy of religion. Barbour's crucial insight was to recognize the similarity between the methodological, linguistic, and epistemological structures of science and theology: Both make cognitive claims about the world expressed through metaphors and models, and both employ a hypothetico-deductive method within a revisionist, contextualist, and historicist framework. This approach, which Barbour called "critical realism," was later pursued in Europe by such scholars as Arthur Peacocke and John Polkinghorne. Theologian Wolfhart Pannenberg introduced to the discussion Karl Popper's understanding of theories as revisable hypotheses in his *Theology and the Philosophy of Science* (1976). Philosopher of religion Nancey Murphy developed a related approach in her *Theology in an Age of Scientific Reasoning* (1990), deploying Imre Lakatos's notion of a "scientific research program," which includes a central commitment or "hard core," a surrounding protective belt of auxiliary hypotheses, and criteria for choosing between competing programs. Additional important contributions came from scholars such as Philip Clayton, Niels Gregersen, Thomas Torrance, and Wentzel van Huyssteen.

The chief concern of these scholars was to create a framework for dialogue that allows for methodological reductionism (studying wholes in terms of their parts and applying successful strategies in one area to others) as a legitimate scheme for scientific research but respects the irreducibility of processes and properties referred to by theology and other higher-level disciplines to those of lower levels (epistemic antireductionism or holism). Some antirealists and postmodernists criticize this broad approach by pointing to difficulties that confront realist interpretations of scientific theories and theological concepts (e.g., quantum mechanics and the idea of "God") and by questioning the "metanarrative" role of science. On balance, though, this methodological bridge remains an enduringly important contribution to the field, both for its crucial historical role and as a point of departure for current research.

Key areas of engagement

In numerous and subtle ways, the contemporary sciences challenge and reshape the God-nature problematic for theological perspectives as diverse as panentheism, process theology, feminist theology, trinitarian theology, neo-Thomism, and evangelical theology. This section briefly reviews several key topics of discussion.

In physics, Albert Einstein's theory of special relativity challenges our ordinary sense of time's flow and the assumption of a universal present moment, problematizing the idea that God experiences and acts in the world in the flowing "now." Equally challenging is the relation between divine action and natural causality. Because Newtonian mechanism depicted nature as a closed causal system, special divine action was subsequently either understood in terms of interventionism or reduced to human subjectivity. Developments in the philosophical interpretation of quantum mechanics, chaos theory, and cosmology (and the neurosciences as well) may provide the basis for a new theory of noninterventionist, objective, special providence. With regard to cosmology, scholars such as Willem B. Drees, George Ellis, Ted Peters, Robert John Russell, William Stoeger, Mark Worthing, and Joseph Zycinski discuss the consonance and dissonance between the theological notion of the universe as "creation" and features of the standard Big Bang scenario including the apparent beginning of the universe ($t = 0$) and the curious fact that physical constants have precisely the values needed for life's emergence (the Anthropic Principle).

In response to biological evolution, theologians such as Barbour and Peacocke champion "theistic evolution," the view that what science describes in terms of evolutionary biology can be seen, from a religious perspective, as God's action in the world. However, billions of years of natural disaster, suffering, death, and extinction of species, not to mention the lack of overall directedness to evolutionary change, present this view with serious challenges. Barbour and Peacocke, along with Holmes Rolston and Thomas Tracy, provide careful assessments of suffering and evil in light of evolutionary theory, and Rolston offers a helpful analysis of the complex role of "values" in nature. Evolutionary and ecological thought also play an important role in Sallie McFague's model of the world as God's body and Rosemary Radford Ruether's discussion of Gaia and God.

How will genetics, sociobiology, the neurosciences, and the computer sciences affect the way we understand the human person? Can we relate knowledge gained from these disciplines to the biblical view of the person as a "psychosomatic unity"? Fruitful insights into these issues come from such scholars as Francisco Ayala, Lindon Eaves, Denis Edwards, Anne Foerst, Philip Hefner, Noreen Herzfeld, and Murphy. Ted Peters and Ronald Cole-Turner also draw together scientific and religious perspectives on important social issues such as genetic discrimination, gene patenting and cloning, stem cell research, genetic determinism and human freedom, and somatic versus germline intervention.

Several of the sciences challenge the theological notion of redemption, which in Christianity draws together the doctrines of incarnation, christology, resurrection, and eschatology. The vast size and complexity of the cosmos force us, whether scientists, persons of faith, or both at once, to look beyond our concern for humanity, or even the Earth, to the destiny of the universe as a whole. Can religious belief countenance the prediction that the universe's far future will be "freeze or fry," either endless universal expansion or violent recollapse? This scientific forecast presents one of the most serious challenges to any belief in human salvation, the meaning and future of life in the universe, or the eschatological consummation of the cosmos as new creation.

Methodological frontiers

Several important concerns are emerging at the frontier of the science and religion discussion. Science itself is increasingly recognized as a thoroughly human endeavor open to the critical insights of, for example, gender analysis. The work of Evelyn Fox Keller and Helen Longino on this topic provides a helpful starting point for gender analysis of the science and religion field itself. Additional voices from the world's religious and indigenous cultures need to be brought into the science and religion discussion to shed new light on the complex relations among science, religion, and culture in an interreligious context. Other important areas include the history of science and religion, the theological critique of scientism, the relation of science to nature and spirituality, the creative roles of philosophy and theology in scientific research, and the possibility of these diverse fields entering into a mutually constructive dialogue where each partner receives something of intellectual value from the other.

See also SCIENCE AND RELIGION, HISTORY OF FIELD; SCIENCE AND RELIGION IN PUBLIC COMMUNICATION; SCIENCE AND RELIGION, METHODOLOGIES; SCIENCE AND RELIGION, MODELS AND RELATIONS; SCIENCE AND RELIGION, PERIODICAL LITERATURE; SCIENCE AND RELIGION, RESEARCH IN

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SCIENCE AND RELIGION, HISTORY OF FIELD

Among many celebrations coinciding with a new millennium was one that had much to do with the subject of science and religion. According to a report by Thomas J. Oord in the January 2002 issue of *Research News and Opportunities in Science and Theology,* at the November 2001 meeting of the

American Academy of Religion (AAR) in Denver, Colorado, "hundreds gathered in the Grand Ballroom to . . . celebrate the remarkable advance of this interdisciplinary field" (p.34). From an earlier obscurity within the AAR, science and religion was now attracting a large audience, boasting a burgeoning literature, and, in some quarters, even claiming to be a new discipline. In the closing years of the twentieth century, a heightened awareness of ethical issues raised by biotechnology, exciting advances in the neurosciences, a greater sensitivity to environmental concerns, and a reconsideration of relations between physical and spiritual health were creating new spaces for dialogue within and between scientific and faith communities. With strong support from philanthropic organizations, particularly the John Templeton Foundation, new research and teaching initiatives were launched, designed to explore the many contexts in which scientific and religious interests might intersect.

Claims for a new field can easily be exaggerated. As James Gilbert observed in *Redeeming Culture* (1997), during the last century a science-religion dichotomy was often used by individuals and organizations in the United States to construct distinctive identities. Without an understanding of the many meanings with which the words *science* and *religion* have been invested, attempts to establish definitive relations between them can easily be naïve. Conversely, definitions proposed for both *science* and *religion* sometimes reflect decisions already taken on the relations between them and how they are to be presented for polemical purposes. Many of the issues currently discussed under the banner of "science and religion" have been recognized from antiquity and have repeatedly been subject to searching analysis. It has even been suggested that the periods during which it has been unfashionable to discuss the mutual bearings of scientific and religious beliefs have been the exception, not the rule. When Alfred North Whitehead (1861–1947) wrote his *Science and the Modern World* (1925), he considered it a matter of urgency that the relations between scientific and religious views of the world should be clarified. And it was already possible for him to argue that, far from a perennial hostility, modern science had been a derivative of medieval theology, and one that could help to purge traditional religions of their superstitious elements. Much earlier still, again with an eye to history, Isaac Newton (1642–1727) had suggested that the sciences had only prospered in monotheistic cultures.

From antiquity to the Middle Ages

Among recurrent issues discussed in antiquity were the nature of causality, the role of a deity or deities in the making of the world, the ultimate nature of matter, the nature of body and soul, and the place of humans in the cosmos. In the works of the Greek atomists, and later Lucretius during the first century B.C.E., a case was made for a naturalistic philosophy in which worlds came into being and passed out of existence as a result of the chance collision of atoms. There might be life on other worlds, and nature could run by itself without the aid of gods. Other ancient thinkers, such as the second-century physician Galen, were more responsive to the appearance of design, especially in anatomical structures. An Epicurean rejoinder was, however, always possible—that the appearance of design was illusory, simply reflecting the fact that nature had experimented with every possible combination of organs and limbs, the nonviable combinations having long since perished.

The relationship between sacred and secular knowledge and the degree to which the physical world could be considered autonomous were issues faced by the early Church fathers, among whom a diversity of views existed. Augustine of Hippo (354–430) addressed the question of whether the exegesis of Scripture should reflect current secular knowledge, observing that too tight a dependency could prove embarrassing when the state of knowledge changed. In both Christian and Islamic cultures the problem of assimilation was thrown into relief by divergent reactions to Aristotle's conception of a world that had existed from eternity. Thomas Aquinas (c. 1225–1274) was to take the sophisticated view that the Christian doctrine of creation, affirming the continual dependence of all that exists on a transcendent being, was compatible with either the eternalist position or with the conception of a definite beginning. Reason alone could not decide the issue. Aquinas also illustrates the practice, many times repeated, of appropriating and modifying certain aspects of the latest science for theological purposes. Aristotle's emphasis on the primacy of final causes (of "goals" inherent in nature) in governing physical processes was attractive because one could ask deeper questions about the coordination of physical processes which, in remarkable combination, constituted a viable world. For Aquinas the natural philosophy of Aristotle was incomplete without the postulation of the "Being" ultimately responsible for the coordination.

Seventeenth- and eighteenth-century discussions

Even such fragmentary examples from the past confirm that what are perceived today as major issues in the field of science and religion have a long history. In seventeenth-century Europe, as today, scientific innovations prompted new forms of theological reflection. Robert Boyle (1627–1691), for example, found evidence of divine craftsmanship in the exquisite structures of minuscule creatures revealed by the microscope. In response to the overly mechanized universe of René Descartes (1596–1650), Newton saw in the gravitational force a source of activity in the natural world that could not be explained by reference to innate properties of matter. In a celebrated controversy that took place in the second decade of the eighteenth century, Newton's defender Samuel Clarke (1675–1729) and the German philosopher Gottfried Wilhelm Leibniz (1646–1716) debated the fundamental question of how a divine being might act in the world. If, as Clarke argued, the laws of nature simply defined the way God *normally* chooses to act, there was nothing in the laws themselves to prevent other divine initiatives. Using an analogy that still has currency, Newton argued that it was easier for God to move and control the matter in the world than it is for people to move and control their limbs. Leibniz, by contrast, insisted that the best of all possible worlds, the world made by God, had to be one that needed no maintenance, and emphatically not the "reformations" of the solar system that Newton required for its continuing stability.

Some three hundred years later, comparable metaphysical positions are being staked out in debates over the sufficiency of evolutionary theory to explain the appearance of design in organic systems. Those who argue for a divinely bestowed functional integrity in nature often resemble Leibniz, while advocates of more interventionist models of divine creativity bear some resemblance to Newton. In the original Newtonian debates, positions of subtlety and sophistication were achieved, Newton arguing that the deity would use secondary causes as instruments of the divine "Will" where they were available. Then, as now, such debates were often infused with political significance, Leibniz seeking to score points against Newton when they were at loggerheads over priority for the calculus and when, with the prospect of the Hanoverian succession to the English throne, Leibniz saw opportunities for advancement in the country of his foe.

From the seventeenth century onwards a discourse involving theological elements has featured in the promotion of the applied sciences and technology. Francis Bacon (1561–1626) argued that empirically based knowledge when applied for altruistic purposes must have a religious sanction and could even restore human dominion over nature which had been lost at the Fall. In one of the manuscripts (Add. 4003) of the Portsmouth collection held in Cambridge University Library, Newton argued that it was not sacrilegious for a chemical initiate to imitate the creative work of the deity because a creator who could produce a cocreator displayed the greater power:

> If any think it possible that God may produce some intellectual creature so perfect that he could, by divine accord, in turn produce creatures of a lower order, this so far from detracting from the divine power enhances it; for that power which can bring forth creatures not only directly but through the mediation of other creatures is exceedingly, not to say infinitely greater.

There is a metaphysical position here, reinforceable through the religious claim that humans are to be collaborators with the deity, which finds expression in current debates in biotechnology. There have long been theological resources for both countenancing and criticizing attempts to improve upon nature. Particularly in dissenting religious traditions, concepts of improvement and concepts of providence have been indissolubly linked, as they were for the eighteenth-century minister and chemist Joseph Priestley. Science was prized by Priestley because, together with a rational religion, it helped to eliminate superstition, to promote human welfare and to explode the "arbitrary power" of an established Church. In his *Disquisitions Relating to Matter and Spirit* (1777), Priestley also reconsidered the relationship between body and mind, preferring a monistic view to the matter/spirit dualism prevalent in Christian tradition.

Such examples indicate that the intellectual preconditions of the "field" of study that is called "science and religion" have long existed and that core issues have been repeatedly discussed as constituents of other fields: philosophy, natural philosophy, and metaphysics. Newton could say that it was part of the business of natural philosophy to discuss the question of God's attributes and relation to the world. But precisely because elements of theology might still be incorporated within natural philosophy, precisely because in the Anglophone world the word *science* did not take on its modern specialized meaning until the nineteenth century, it would be anachronistic to ask how a field of "science and religion" might have been constituted in earlier periods.

In specific European contexts there were also political pressures that could undo attempts at what today might be described as dialogue. In eighteenth-century France, Voltaire popularized Newton's natural philosophy as part of his attack on the power of the Catholic Church, whose intolerance toward other religious persuasions he deplored. In eighteenth-century Germany, Immanuel Kant exposed the logical weakness of attempts to argue for a deity on the basis of what was known of nature. The practice of natural science had to proceed on the supposition that nature behaved *as if* it were orderly and designed, but the "as if" introduced an element of agnosticism. In eighteenth-century Edinburgh, David Hume did construct a dialogue—his scintillating *Dialogues Concerning Natural Religion* (1779). These were designed, however, to expose the fragility of the analogies on which the design argument rested. Even if the natural world did resemble a human artifact, such as a clock or a ship, it did not follow that it was made by only one artificer, and certainly not one whose attributes necessarily coincided with those assumed in the main religions. Behind Hume's critique was an ethic of civic virtue, a commitment to the material improvement of his society and at odds with what he despised as the "whole train of monkish virtues."

Nineteenth- and twentieth-century research

During the nineteenth and twentieth centuries there were innumerable critiques of religious discourse, contributing to forms of skepticism that would militate against sympathetic attempts at dialogue. In the positivism of Auguste Comte (1798–1857), human culture, through the facts and laws established by the sciences, was emancipating itself from the theological and metaphysical stages of its development. In England the scientific naturalism of Thomas Henry Huxley (1825–1895) was an ideological as well as a methodological tool in the promulgation of professional standards that would exclude the clerical amateur. Battling to gain greater cultural authority for the sciences, Huxley found in Darwinian evolution welcome support for the continuity and sufficiency of natural causes in accounting for human origins. In the early twentieth century the austere logical positivism of the Vienna Circle precluded meaningful dialogue between science and religion because only scientific propositions had the essential virtue of verifiability. Pretensions to reinterpret religious beliefs in the light of modern science have not surprisingly encountered resistance from theologians themselves, especially those who have shared Karl Barth's (1886–1968) perception that natural theologies (with their tendency to naturalize prevailing but sometimes insidious social and political orders) embody the presumption of human reason rather than the gift of grace in calls to a spiritual life.

Such deterrents have left their mark, but so too have the pressures that have encouraged assertions of complementarity and efforts at integration. Of these pressures two have been paramount: the desire of scientists with religious convictions to harmonize their loyalties; and the desire of religious institutions to deflect anticlerical hostility. Galileo Galilei (1564–1642) provides an excellent example of the former, since he wished to show that a loyal Catholic could be at the frontier of physical science. The Vatican itself, so often vilified for having condemned him, provides an example of the latter in its reestablishment of an observatory to demonstrate that it was not opposed to the exploration of God's creation. In his announcement in 1891, Pope Leo XIII said that the plan was that everyone might see that the Church and its pastors were not opposed to true and solid science but that they embraced it, encouraged it, and promoted it with the fullest possible dedication. An opportunity to do so arose when the Vatican Observatory contributed to a major international collaboration, involving a total of eighteen observatories, in which the entire sky was to be mapped and photographed.

Other pressures, too, have sustained a discourse of science and religion. For much of the nineteenth century new scientific theories were examined for their religious implications and often viewed with suspicion if they appeared subversive. Theories of evolution would be a prime example, Darwin smarting from the fact that his contribution was often judged more by its supposed religious ramifications than for its scientific merits. The popularization of science was a task in which it was always tempting to invoke a supposed relevance to religion as a way of winning attention, a practice still visible today as science writers reserve a place for God in their titles if not in their universe. It has been observed of the mid-Victorian period that many members of the public were more interested in science versus religion than in science. In some parts of the world this may still be true, with the caveat, now as then, that much of the conflict has been between competing methods of harmonization.

Until the third quarter of the nineteenth century there would have been little evidence from the titles of books that a separate *field* of study bearing the description "science and religion" might be constituted. Polemical works could, however, set an agenda and two were to prove extremely influential: John Draper's *History of the Conflict between Religion and Science* (1875) and Andrew White's *A History of the Warfare of Science with Theology in Christendom* (1895). Strong personal motives were at work in each. Draper's *History* was a Protestant tirade against the Catholic Church, energized by his reaction to the encyclical *Quanta cura* (1864) and to the assertion of papal infallibility (1870), which he saw as epitomizing illegitimate constraint on the freedom of scientific enquiry. White's *History* reflected animosity toward the dogmatism he had encountered when, as a consequence of advocating a nonsectarian charter for Cornell University in Ithaca, New York, of which he was the first President, he had incited stormy reactions from clerics wishing to preserve their hold over education. Because of the historical orientation of these works, and their more tendentious claims, an important precursor of the modern field took shape in a body of historical literature of increasing sophistication in which the inadequacies of the conflict metaphor were exposed. For example, James Simpson's *Landmarks in the Struggle between Science and Religion* (1925) was deeply critical of Draper and White for their unsympathetic treatment of the early Church Fathers, notably Augustine, a historiographical correction that continues today. Revisionist literature has recognized a tension among the Church fathers between approving the study of nature and warning that it must not displace the higher priorities of the spiritual life. Classic texts in the history of science, such as E. A Burtt's *The Metaphysical Foundations of Modern Physical Science* (1949), E. J. Dijksterhuis's *The Mechanization of the World Picture* (1961), Robert Merton's *Science, Technology, and Society in Seventeenth-Century England* (1938 and 1970), Charles Webster's *The Great Instauration* (1975), and many more, identified respects in which religious values and beliefs had provided stimulus and not merely obstruction to scientific activity. Historians of science with Catholic, Protestant, and Marxist sensibilities, such as Stanley Jaki, Reijer Hooykaas, and Joseph Needham, respectively, helped to create a literature in which religious variables were germane to any discussion as to why the scientific movements of the sixteenth and seventeenth centuries had proved more enduring in Europe than elsewhere.

In 1962 the work of another historian of science, Thomas Kuhn's *The Structure of Scientific Revolutions,* with its telling critique of linear models of scientific progress, contributed to an emerging disenchantment with positivist accounts of scientific rationality. By focusing on the shared beliefs of scientific communities and the clash of incommensurable paradigms at times of revolution, Kuhn among others emphasized a social dimension to scientific practice that was subsequently explored in depth. As historians and sociologists became increasingly sensitive to the ways in which social, economic, and political forces had shaped the sciences in local contexts, so the relevance of religious variables had also to be taken seriously.

A field of study is one that can be mapped, and during the 1960s such a map appeared in the shape of Ian Barbour's *Issues in Science and Religion* (1966). Significantly, this work also began with a historical overview, but took within its purview the methods of science; the question of objectivity and personal involvement in both the natural and social sciences; the methods of religion; the languages of science and religion; the implications of the indeterminacy arising from quantum physics; the physical basis of life; and the many issues that could be subsumed under "Evolution and Creation." The existence of such a comprehensive text helped to make possible the teaching of courses on science and religion in the late 1960s. Such courses were increasingly visible during the 1970s in both Great Britain and North America. In Britain, for example, several thousand Open University students took a course entitled "Science and Belief from Copernicus to Darwin" that was launched in 1974, and later "Science and Belief from Darwin to Einstein." As a consequence, good quality teaching materials, complemented by radio and television programs, were produced that allowed students to assess their own understanding and progress.

References to teaching remind us that the cultivation of a field assumes not only a map but also an institutional base. In the United States, associations dedicated explicitly to "science and religion" began to appear in the middle years of the twentieth century. They multiplied as a need was felt to address the adversarial positions that manifested themselves in public on such matters as the status of scientific expertise, the moral implications of nuclear weapons, the wisdom of genetic engineering, and the seriousness of environmental degeneration. An early association was the Institute on Religion in an Age of Science (IRAS) founded in 1954 by Ralph Burhoe and Harlow Shapley. Enjoying support from Unitarian constituencies, it sought a new religiousness derivable from science. For Burhoe this required a detailed evolutionary cosmology with science as its base. For Shapley too it meant the proclamation of scientific primacy in religious contexts, which could however attract pessimistic responses even from sympathetic scientists. The neurophysiologist R. W. Gerard could not think that the great bulk of people would accept the austerity of a rational religion any more than they accepted the austerity of science. His question would still be salient in many contexts: How can publicly misunderstood science and publicly dogmatic religion ever illuminate each other? In 1966, Burhoe, with Shapley's aid, established the journal *Zygon,* diverse in the essays it has published, but retaining a vision of unity between science and religion, achievable through the scientizing of theology. Twenty-five years earlier, another enduring organization, with quite different objectives, had taken shape—the American Scientific Affiliation (ASA). Having evangelical roots, the ASA wished to promote a unity between the sciences and the fundaments of a biblical theology. One of its immediate postwar tasks was to produce a science handbook for college students, reflecting the concern of its leaders that the nation's universities had ceased to be Christian.

Most of the earliest organizations dedicated to an underlying unity of science and religion had their distinctive religious agendas, which could make cooperation difficult. An attempt in 1958 to establish a formal link between the ASA and the Society for the Scientific Study of Religion (SSSR), which had been founded in 1949 to explore the relations between religion and the social sciences, ended in failure. The very meaning of the word *religion* was often a bone of contention. In Europe as well as North America, societies for the study of science and religion increased in number during the latter part of the twentieth century. A moving spirit in England was Arthur Peacocke who founded a Science and Religion Forum and a Society of Ordained Scientists. Out of the Research Scientists Christian Fellowship, a branch of the evangelical Inter-Varsity Fellowship, a Christians in Science association was formed, publishing the journal *Science and Christian Belief.* A step toward a more international association was taken with the inauguration in 1986 of the European Society for the Study of Science and Theology (ESSSAT), which continues to hold biennial conferences and to award prizes for promising work by young scholars.

The expansion of a field, especially one seeking greater academic recognition, can be difficult when academic and apologetic goals are not clearly distinguished. Even if the majority of scientists do not share the strident antireligious rhetoric of well-known science writers, it has long been part of scientific culture that scientific academies are not the place for religious debate. The common conviction that a person's religion is a private matter adds to the reticence and the resistance. Issues discussed at conferences on science and religion can sometimes seem naïve to historians and philosophers who may observe the reinvention of wheels that turn on axioms long since discredited. A constraint of a different kind concerns the dearth of career opportunities, particularly within academe, for those whose research has been in such an interdisciplinary and multidisciplinary arena.

At the beginning of the twenty-first century, it is, however, possible to discern signs and advances that may presage a shift into a less transitional state. Those scientific societies concerned with the public image of science, such as the British and American Associations for the Advancement of Science, have opened their doors wider for sessions on science and religion. The European Science Foundation has sponsored workshops on the theme of science and human values. During the 1990s, there was a quantum leap in the number of courses on science and religion taught in universities and colleges of higher education. This was in large measure due to incentives provided by the John Templeton Foundation, which defines its mission as the pursuit of "new insights at the boundary between theology and science through a rigorous, open-minded and empirically focused methodology," privileging the "methods and resources of scientific inquiry having spiritual and theological significance." Independently of such support, academic posts were created during the 1990s at Britain's oldest universities with science and religion as their specified field—the Starbridge Lectureship in Cambridge and the Andreas Idreos Chair in Oxford. Though few in number, chairs in science and religion have also been established elsewhere. The first of these, the James I. McCord Chair in Theology and Science, was established at the Princeton Theological Seminary in New Jersey. Other American centers have been particularly active in cultivating the field, especially the Center for Theology and Natural Sciences (founded by Robert J. Russell in 1981) in Berkeley, California, and the Chicago Center for Science and Religion (founded in 1988). New encyclopedic works of reference have begun to appear (of which this is an example), including *The History of Science and Religion in the Western Tradition* (2000) published by Garland. The year 2002 saw in Granada, Spain, the first meeting of a new *International Society for Science and Religion,* part of whose mission was to embrace and encourage the discussion of science and religion in religious traditions other than Christianity. In a world where partisan and warring identities are still so strongly reinforced by religious beliefs, few would deny that such interfaith dialogue has become as great a priority as a disembodied dialogue between science and religion.

See also BUDDHISM, HISTORY OF SCIENCE AND RELIGION; CHINESE RELIGIONS, HISTORY OF SCIENCE AND RELIGION IN CHINA; CHRISTIANITY, HISTORY OF SCIENCE AND RELIGION; HINDUISM, HISTORY OF SCIENCE AND RELIGION; ISLAM, HISTORY OF SCIENCE AND RELIGION; JUDAISM, HISTORY OF SCIENCE AND RELIGION, MEDIEVAL PERIOD; JUDAISM, HISTORY OF SCIENCE AND RELIGION, MODERN PERIOD

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JOHN HEDLEY BROOKE

SCIENCE AND RELIGION IN PUBLIC COMMUNICATION

After World War II, the United States faced a considerable challenge: How would communications continue in the aftermath of a nuclear war? The solution proposed was a network of computers that had no central authority and were capable of almost infinite message rerouting. This system, known as ARPANET (Advanced Research Projects Agency Network), debuted in 1969. Telenet, the first commercial version of the ARPANET, appeared in 1974. In 1979 the first network-wide discussions groups were up and running as USENET. But before cyberspace could become readily navigable, hypertext, the World Wide Web, and search engines had to be developed. The first point-and-click way of navigating Internet files, known as *gopher,* was released in 1991, and the same year the first computer code of the World Wide Web debuted in the relatively innocuous newsgroup alt.hypertext. Thus, the rich global communications medium called the Internet was born.

By the mid-1990s several science and religion organizations had a basic presence on the World Wide Web. Typically this consisted of information about the organization and its upcoming events and programs. One of the first sites of this kind was a web site for the Institute on Religion in an Age of Science (www.iras.org). Online discussion on science and religion topics was initially confined to private email distribution lists and various USENET newsgroups such as *The Talk.Origins Archive* (www.talkorigins.org), which covers the creation/evolution controversy.

The need to handle an ever increasing number of discussion participants led to the employment of listservs (managed email discussion lists), such as the *Meta-lists,* now *Metanexus,* which began operating in 1997. An "edited, moderated, and public listserv dedicated to promoting the constructive engagement of science and religion and to sharing information and perspectives among the diverse organizations and individuals involved in this interdisciplinary field," by 2002, *Metanexus* had over six thousand subscribers in approximately sixty countries.

By their second generation, many web sites had incorporated some basic science and religion content in addition to the organizational information. Initially the content was preexisting text made available in plain electronic form, but there has been a constant evolution in the sophistication with which the web has been used to present science and religion content.

In 1998, the Counterbalance Foundation based in Seattle, Washington, in conjunction with the Center for Theology and the Natural Sciences (CTNS) in Berkeley, California, developed a suite of interactive topics specifically for the web. Initially available at the web site for the PBS/New River Media documentary television program *Faith and Reason,* (www.pbs.org/faithandreason) the content was also accessible from www.ctns.org and www.counterbalance.org. This suite was tailored to the web in three ways: It included extensive use of hypertext linking, a writing style that allowed the reader to visit topics in any particular order, and use of streaming audio. These features allowed readers from diverse backgrounds to approach the same content and follow different paths through it. The availability of streaming audio opened up the appeal of science and religion topics to a still broader audience.

In 2000, Counterbalance combined the CTNS content with new material, including the textbook *God, Humanity, and the Cosmos* (1999) edited by Christopher Southgate, to create the *Meta-Library.* The *Meta-Library* is a single shared location that provides content to several science and religion sites, most notably www.metanexus.net. As of 2002, the *Meta-Library* had over one hundred hours of interactive video material and thirty thousand links in the text material.

By mid-2002, the web was home to a variety of sites on science and religion that were diverse both in terms of approach and services offered; the Yahoo! directory contained links to dozens of web sites on evolution and creation alone. Some science and religion sites were still primarily informational, such as those of the American Scientific Affiliation (www.asa3.org), the American Association for the Advancement of Science site for DoSER (Dialogue on Science, Ethics, and Religion; www.aaas.org/spp/dser), and the National Academy of Science's site on science and creationism (www7.nationalacademies.org/evolution). Others web sites offered both information and discussion. Exemplars are the *Access Research Network* (www.arn.org), which discusses Intelligent Design theory, and *Metanexus.* Furthermore, such undertakings as *Project Gutenberg* (www.gutenberg.net) and the *Internet Public Library* (www.ipl.org) guaranteed that the classic texts of luminaries such as Charles Darwin, Thomas Henry Huxley, and Alfred Russel Wallace were available to the global public. In summary, persons all over the planet had access a vast repertoire of information on science and religion.

The future holds several possibilities. The web will continue to be an effective medium through which science and religion organizations can reach out to both the academic and broader community. Increase in fast "broadband" access to the web will allow sites to become progressively richer and more interactive, and will provide more video, including interviews and conference presentations (available both live and archived for later access), real-time chat rooms, tutorials, and so on. The content will no doubt broaden in scope, reaching beyond the core sciences and core religions, and become available in languages other than English. The conversation will also become more "world-wide" as the cost of computer equipment and web access allows smaller institutions and local societies to make use of the medium. In addition, an increasing number of distance education courses in science and religion will likely become available. However, the so-called digital divide must also be considered. While the dialogue between science and religion is certain to have a bright future on the Internet, participation in this part of the conversation will remain restricted to that small fraction of the global community with access to the necessary technology. This is likely to remain a real issue into the far future.

See also INFORMATION TECHNOLOGY; SCIENCE AND RELIGION, PERIODICAL LITERATURE

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SCIENCE AND RELIGION, METHODOLOGIES

A primary concern of contemporary scholarship on science and religion is the question of precisely how the two areas should be related. Historically, there has been a wide range of such theories. While the situation is in many ways similar today, the growth of a specific field of religion and science has provided some increased sophistication. Modern methodologies of science and religion generally seek to do two things. First, any methodology of science and religion almost inevitably has to give an account of the nature of both science and religion. That is, it must give an account of the realities that science and religion each describe, as well as how knowledge in each field is acquired. Second, any methodology must then account for how the truths in the respective fields can be related to one another. Most current methodologies of science and religion attempt both these tasks to varying degrees. In much of the current literature on science and religion methodology, the sciences in question are usually the physical and biological sciences, while the aspects of religion of most concern are the theological and metaphysical claims that undergird religious life and practice.

Independence models

For much of the twentieth century, many (if not most) philosophers and theologians conceived of religion and science as two completely separate disciplines that were each legitimate in their own right but which explained or described completely different realms of experience. Of these, the earliest was the theological movement of neo-orthodoxy, championed in particular by Swiss theologian Karl Barth (1886–1968), but widely represented in both Europe and the United States. Neo-orthodox theologians emphasized revelation as the primary means of knowing God, and they emphasized the separateness of this revelation from all other spheres of knowledge. This emphasis on the uniqueness of theology with respect to the sciences tended to also be supported by existentialist theologians such as Paul Tillich (1886–1965) and Rudolf Bultmann (1813–1855).

Independence models of religion and science received a further boost from the mid twentieth-century development of linguistic philosophy, deriving primarily from the later works of Ludwig Wittgenstein (1889–1951), who argued that human discourse and knowledge could best be understood as separate and incommensurable language games that each possess a unique vocabulary and logic. In some versions of this, science could be said to be about facts, religion about values. Both areas of practice and experience are equally legitimate, but cover completely separate spheres of life. In some later writings, this mode of independence received metaphorical support from the idea of complementarity derived from the Copenhagen interpretation of quantum physics championed by Niels Bohr (1885–1962). Just as modern physics was forced to alternatively describe subatomic particles as either waves or particles, but not both simultaneously, so too could religion and science be understood as giving complementary but distinct accounts of reality. Once again, both religion and science are legitimate areas of inquiry and practice, but are pursued and understood separately.

Forms of these independence models remain championed today. Neo-orthodoxy's emphasis on the separate character of religion strongly influenced British theologian Thomas Torrance and, more recently, Alistair McGrath. Paleontologist and science writer Stephen Jay Gould (1941–2002) also attempted to revive the linguistic philosophy version of independence. Despite this, these are now minority views for a number of reasons. Independence views presume that a clear distinction can be made between the provinces of science and religion, with an implication either that religion does not rely on facts about the world or that the facts of religion and the facts of science are completely different. Historically, however, this has not been the case, and most modern theologians believe that there are at least important border areas where science and religion overlap. Moreover, the more general theological and philosophical frameworks (particularly neo-orthodoxy and linguistic philosophy) are no longer seen to be nearly as persuasive as they once were, with the result that their more specific claims about the relationship of science and religion are found wanting.

Critical realism as a default view

Among current views of the relationship of religion and science, the most prominent has been that of critical realism. This prominence is due in no small part to its advocacy by three of the most important contributors to the field of science and religion: Ian Barbour, Arthur Peacocke, and John Polkinghorne, all three originally practicing scientists who later wrote on issues of religion and science. On the critical realist view, both religion and science describe the world as it is, and so there is some correspondence between the statements of religion and science and the real world that such statements describe. Critical realism differs from a naïve realism, however, in its recognition of the role of the possibility of error, bias, and partiality in all descriptions.

The most elaborate defense of critical realism within the field of science and religion has been given by Ian Barbour. Drawing on the philosophy of science of Thomas Kuhn (1922–1996) and others, Barbour argues that both science and religion have elements of subjectivity in their models of the world. While theories are based on evidence, they consistently overdetermine it. Consequently, theory choice is never simply a matter of verification or falsification, but includes criteria of coherence, scope, and even beauty. The way that a theory speaks of the world may thus be rather indirect, depending on data but not determined by it.

For critical realists, science and religion both provide partial views of the world that may overlap on a range of issues. Arthur Peacocke has argued that theology can be placed along a hierarchy of knowledge, with physics providing the most basic facts at the lowest level and theology providing the most general at the highest level. Because there can be significant overlap between science and religion on particular issues such as cosmic origins and human nature, critical realism is committed to providing theological perspectives that are capable of harmonizing with modern science.

While critical realism has been highly influential within the field of science and religion, it has also been the subject of significant criticism. The issue of how exactly scientific and especially religious models can be said to correspond to reality has been especially problematic. The more one acknowledges the critical element in any theory or model, the less realist it seems to be, a problem that is well recognized more broadly in the philosophy of science. Despite much early work in promoting critical realism, its advocates have yet to provide a sophisticated response to its critics, and for this reason its appeal has languished some since the 1990s.

Alternative methodologies from the philosophy of science

Despite the perceived shortcomings of the critical realist movement, it has been highly influential in its view that science and religion (and, more specifically, theology) can be said to employ similar methods of exploring reality, thus providing a basis for dialogue and engagement between the two areas of experience. Reasons for this view stem not only from critical realism, but also from more general developments in the philosophy of science, from which critical realism also drew. Consequently, there has been widespread support for employment of insights from the philosophy of science for explaining the nature and relationship of religion and science, even though significant disagreement remains as to whose philosophy of science should be employed and to what extent. While critical realists such as Ian Barbour were influenced by the work of Thomas Kuhn, German theologian Wolfhart Pannenberg utilized the earlier philosophy of science of Karl Popper (1902–1994), arguing that theological claims should be capable of being falsifiable, just as Popper argued that scientific claims should be. A number of theologians and philosophers of religion, including Philip Hefner, Nancey Murphy, and Philip Clayton, have preferred to build on the thought of Hungarian philosopher of science Imre Lakatos (1922–1974). Influenced by both Popper and Kuhn, Lakatos argued that science should be understood in terms of competing research programs, each with an unfalsifiable core, which nevertheless must prove to be progressive over time.

Notable in these approaches is an abandonment of a strong commitment to a metaphysical realism for explaining the nature of both science and religion. Murphy has been the most vocal in rejecting realism as an explanatory category, and has argued, following philosopher W. V. O. Quine (1908–2000), that foundationalism, the view that knowledge claims can be deductively built one on another, must be abandoned. Rather, human beings build webs of belief that are complexly interconnected, but with only a weak sense (if that) of some beliefs being more primary than others. Nevertheless, there remain clear criteria for preferring some beliefs and theories over others.

Philosophy of science and post-modernism

The abandonment of both foundationalism and realism are important elements of the broad set of movements characterized as postmodern. A general feature of post-modern movements have been an increased skepticism towards certainty of knowledge, especially with regard to the sciences, combined with a deep awareness of hidden ideologies in apparently objective knowledge claims that influence power relations of race, class, and sex. Feminist philosophers of science such as Sandra Harding and Evelyn Fox Keller have noted how sexual bias can pervade scientific theory and practice. Advocates of the strong program of sociology of science such as Steve Fuller have argued that science, in essence, has no objective basis and is simply one discourse among others. Taken to extremes, such views are debilitating to a science and religion dialogue, as they destroy any possible ground of knowledge. There are, however, profound insights to be derived from these postmodern approaches, and these have been, to varying degrees, employed by some science and religion scholars. Theologian J. Wentzel van Huyssteen has attempted to carefully incorporate a postmodern, postfoundationalist critique while still maintaining the legitimacy of both science and religion as intellectual endeavors. Distinctly feminist perspectives have had a harder time entering into the mainstream of religion and science scholarship, although a number of elements of feminist thought (e.g., an abandonment of dualism, rejection of foundationalism, and an acknowledgement of ideological bias) are now widely acknowledged.

An alternative approach to a number of characteristically postmodern perspectives has been provided by process theology, which received initial inspiration from the philosophy of Alfred North Whitehead (1861–1947). Rather than drawing on the philosophy of science, process theology is based on a broader metaphysical perspective that encompasses both science and religion. Theologian David Ray Griffin has argued at length for a new understanding of naturalism that is based on process theology and does not exclude God. Because of its metaphysical commitment, process theology does not share the skepticism of other forms of postmodernism, and claims some confidence about providing a robust understanding of the world and, consequently, of religion and science.

Prospects

The 1980s and 1990s saw a particularly rich discussion of religion and science methodological issues. Despite this, there remains a considerable array of opinions about the proper relationship of religion and science, both within the field of religion and science proper as well as outside of it. It should be expected that the philosophy of science will continue to play an important role in methodological research, particularly since most of the philosophy of science research currently cited in the field of religion and science dates before 1980. Among perspectives from philosophy of science that may play an increasing role are characterizations of the practice of science as a process of inference to the best explanation (employed by some) and characterizations based on information and probability theory.

A number of methodological perspectives remain under-represented in the field of religion and science. Most notable of these may be the philosophical movement of pragmatism, founded by Charles Sanders Peirce (1839–1914) and William James (1842–1910) and now widely represented in the United States and abroad. Likewise, more radical forms of postmodernism need to be engaged at a more serious level than has been the case to date. A further complicating factor is the growing engagement of a number of the world religious traditions, whose different presuppositions will likely alter perceptions of how religion and science should, in the end, be related.

See also SCIENCE AND RELIGION; SCIENCE AND RELIGION, HISTORY OF FIELD; SCIENCE AND RELIGION IN PUBLIC COMMUNICATION; SCIENCE AND RELIGION, MODELS AND RELATIONS; SCIENCE AND RELIGION, PERIODICAL LITERATURE; SCIENCE AND RELIGION, RESEARCH IN

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SCIENCE AND RELIGION, MODELS AND RELATIONS

A number of categories have been proposed for classifying diverse views of how science and religion can be related to each other. John Haught has suggested the categories of Conflict, Contrast, Contact, and Confirmation. A more detailed eightfold classification has been offered by Ted Peters. This article uses a fourfold typology proposed by Ian Barbour: Conflict, Independence, Dialogue, and Integration.

Conflict

The trial of the Italian astronomer Galileo Galilei in 1633 is often cited as the first prominent example of the conflict of religion with modern science. However, several factors in this trial were not typical of conflicts in subsequent centuries. Galileo challenged the respected authority of Aristotle who had held that the sun and planets revolve in orbits around the earth. Galileo also challenged the authority of the Catholic church at a time when it felt threatened by the Protestant Reformation. He did indeed challenge the literal interpretation of scripture, but this was not crucial in his day because metaphorical and allegorical interpretations of scriptural passages had been widely accepted since the writings of Augustine of Hippo in the 5th century.

Responses to Charles Darwin's *On the Origin of Species* (1859) provide examples of Conflict, but also examples of alternative responses. A long, gradual process of evolution clearly conflicts with the seven days of creation in Genesis, which some theologians interpreted literally. Some religious conservatives accepted a long evolutionary history, but insisted on the special creation of the human soul, whereas liberals were soon speaking of evolution as God's way of creating. The evolutionary origins of humanity seemed a threat to human dignity, especially when "the survival of the fittest" was used by several social philosophers to justify ruthless economic competition and colonialism. After all, the idea of an impersonal process of variation and natural selection challenged the traditional idea of purposeful design. Darwin himself did not believe that every species had been specifically designed by God, but he did believe that God had designed the whole process through which differing species had evolved.

The Conflict thesis is represented today by two views at opposite ends of the theological spectrum: creation science and scientific materialism. Each gains a following partly by its opposition to the other. The popular image of "the warfare of science and religion" is perpetuated by the media, for whom controversies provide dramatic stories.

Creation Science. Fundamentalism, started as a movement in the United States since early in the twentieth century that took a strong stand defending biblical inerrancy. In the Scopes trial in Dayton, Tennessee, in 1925, fundamentalists argued that the teaching of evolution in the schools should be forbidden because it is contrary to scripture. Beginning in the 1960s, proponents of creation science have claimed that there is scientific evidence against evolutionary theory and evidence for the sudden appearance of creatures in their present forms. Several state legislatures passed laws requiring that creationist theory be given equal time with evolutionary theory in public high school biology classes. But in 1987, the U.S. Supreme Court ruled that creation science does not constitute legitimate science and that it has been promoted in order to support a particular religious viewpoint, which is prohibited by the separation of church and state in the U.S. Constitution.

More sophisticated critiques of Darwinism have appeared in recent years, focusing on the rarity of transitional forms between species in the fossil record, and pointing to the sudden burst of new species in the early Cambrian period. According to the biochemist Michael Behe, the complex sequences of molecular reactions in organisms today could not have arisen gradually because if even one step were missing the sequence would not fulfill an adaptive function. Proponents of *intelligent design,* such as William Dembski, assert that such complexity could only be the product of purposeful intelligence. A number of biologists have replied that there are plausible Darwinian explanations for many of these phenomena, and that where such explanations are lacking one should seek more adequate testable hypotheses rather than positing supernatural intervention, which would inhibit rather than encourage further research.

Scientific materialism. Materialism is the assertion that matter is the fundamental reality in the universe. Materialism is a form of *metaphysics* (a claim concerning the most general characteristics and constituents of reality). Scientific materialism makes a second assertion: The scientific method is the only reliable path to knowledge. This is a form of *epistemology* (a claim concerning inquiry and the acquisition of knowledge). The two assertions are linked; if the only real entities are those with which science deals, then science is the only valid path to knowledge.

In addition, many forms of materialism express *reductionism.* Epistemological reductionism claims that the laws and theories of all the sciences are in principle reducible to the laws of physics and chemistry. Metaphysical reductionism claims that the behavior of any system is determined by its component parts, which alone are causally effective.

Two well-known sociobiologists have explicitly defended scientific materialism. Richard Dawkins argues that evolution provides proof that there is no purpose in the universe. He holds that our actions are determined by our genes, which are the product of deterministic laws and chance events. He asserts that religion has always been harmful to human welfare. Edward O. Wilson believes that all human behavior can be explained by biological origins and genetic inheritance. He acknowledges that religious traditions served a useful function in the past by uniting groups around common loyalties, but he argues that this function can be better served today by loyalty to science. Critics suggest that scientific materialism is an interpretive philosophical position that conflicts only with other philosophical and religious positions, not a scientific theory that is part of science itself.

Independence

Conflicts between science and religion can be avoided if they are taken to be inquiries in separate domains. They employ differing languages fulfilling contrasting functions in human life. Science asks about lawful regularities among events in nature, whereas religion asks about ultimate meaning and purpose in a wider interpretive framework. If both science and religion are selective, neither can say that its account of reality is complete.

Separate domains. Starting in the nineteenth century, biblical scholars used historical methods to study the cultural context in which various parts of the Bible were written. They noted that the creation stories of the Bible made significant affirmations that the world is good, orderly, and dependent on a purposeful God. These convictions were conveyed through a symbolic and poetic story that assumed the prescientific cosmology of its day, which included a seven-day creation, an earth-centered astronomy, and a three-part universe with heaven above and hell below the world. But the central message of Genesis can be accepted today because it is not dependent on its ancient cosmology, and it is also quite independent of modern scientific cosmology. Its message is not actually about events in the past, but about the fundamental relation of God to the world and to persons in every moment, which is not a scientific question. Cultural anthropologist point out that creation stories around the world provide models for human behavior. Communities participate in such stories by enacting them in rituals. The role of creation stories is primarily to provide patterns for human life in the present rather than to provide explanatory accounts of events in the past.

The idea of separate domains has also been defended by some natural scientists. The biologist Stephen Jay Gould uses the Latin word *magisterium* to refer to a domain of teaching authority. "The magisterium of science covers the empirical realms, what is the universe made of (fact) and why does it work this way (theory). The magisterium of religion extends over question of ultimate meaning and moral value" (p. 6). Each domain has its own distinctive questions, rules, and criteria of judgment. Gould is critical of scientists who try to derive philosophical, theological, or ethical conclusions from science. He points out that Darwin's idea of natural selection has been misused to defend war, colonialism, ruthless economic competition, and eugenics.

Differing languages. Among philosophers in the 1950s, the logical positivists took scientific statements as the norm for all cognitive assertions and claimed that any statement not subject to empirical verification is either meaningless or purely emotive. In response, the analytic philosophers insisted that differing types of languages serve differing but equally legitimate functions in human life, and each has its distinctive rules. Science and religion do different jobs and neither should be judged by the standards of the order. Science asks strictly delimited questions in the interest of prediction and control. Religious language expresses a way of life through the rituals, stories, and practices of a religious community. The analytic philosophers have usually accepted an instrumentalist account of both science and religion. Both forms of language serve useful practical functions and neither of them need to make truth claims that might lead to conflict.

Critics reply that religious language presupposes distinctive religious beliefs. Classical realism had taken both scientific theories and religious beliefs to be descriptions of reality in itself. At the opposite extreme, instrumentalism took theories and beliefs to be useful fictions serving pragmatic human purposes. Critical realism has defended a middle ground in which conceptual models in both fields make tentative cognitive claims as imaginative representations of aspects of reality in its interaction with human observers.

Science and religion are sometimes said to offer complementary perspectives on the world that supplement rather than compete with each other. Some authors draw a more specific analogy to the Complementary Principle in physics. Physicist Niels Bohr noted that a subatomic entity such as an electron or a photon of light sometimes behaves like a wave and sometimes like a particle; it cannot be represented by a single model. Some authors have extended the principle to characterize the relation between science and religion. The idea of complementarity is a reminder that no set of concepts provides an exhaustive description of reality.

Dialogue

Dialogue portrays more constructive relationships between science and religion than does either the Conflict or the Independence view, but it does not offer the degree of conceptual unity claimed by advocates of Integration. Independence emphasizes differences between science and religion, whereas Dialogue emphasizes several kinds of similarity including the *presuppositions* and *boundary questions* of the scientific enterprise and *methodological* and *conceptual parallels* between the two fields.

Presuppositions and boundary questions. Historians have wondered why modern science arose in the Judeo-Christian West among all world cultures. Some suggest that the doctrine of creation helped to set the stage for scientific activity. Both Greek and biblical thought asserted that the world is orderly and intelligible. But the Greeks held that this order is necessary and therefore one can deduce its structure from first principles. Only biblical thought held that God created both form and matter, so the world did not have to be as it is, and the contingent details of its order can be discovered only by observation. Historians say that many factors contributed to the rise of modern science, including the humanistic interests of the Renaissance and the growth of commerce and trade, but they point out that the idea of creation gave religious legitimacy to scientific inquiry. Many of the founders of modern science believed that they were studying the handiwork of the Creator.

Boundary questions are raised but not answered by science. Why is the universe intelligible? Why is there a universe at all? The cosmologist Stephen Hawking writes: "What is it that breathes fire into the equations and makes a universe for them to describe? The usual approach of science of constructing a mathematical model cannot answer the questions of why there should be a universe for the model to describe" (p. 174).

The cultural contexts of both science and religion have been explored by feminist authors. They have pointed to correlations among the polarities that have been pervasive in Western thought: mind/body, reason/emotion, objectivity/subjectivity, domination/submission, power/love. In each case, the first term of each pair (mind, reason, objectivity, domination, power) is identified in our culture as male, the second term (body, emotion, subjectivity, submission, love) as female. A historically patriarchal culture in which men have held most of the positions of power perpetuated a predominantly male image of God. Moreover the first term of each pair has been prominent in science, especially in its attempt to dominate and control nature. Feminist sensibilities, it is said, might lead to new topics for scientific research, more holistic theoretical concepts, and more ecological technologies. On the religious side, radical feminists turn to indigenous cultures for feminine symbols of the divine and for recovery of the sacred in nature. Reformist feminists, on the other hand, believe that the patriarchal features of historic Christianity can be rejected without rejecting the whole tradition, and they seek to relate this understanding to new possibilities in science.

Methodological and conceptual parallels. It has often been assumed that science is strictly objective. It is said that theories are validated by their agreement with indisputable theory-free data that are unaffected by individual preference or cultural influences. By contrast, religion seems to be highly subjective and strongly influenced by individual and cultural assumptions. But historians and philosophers have called into question this sharp contrast, arguing that science is not as objective nor religion as subjective as had been assumed. There are indeed differences of emphasis between the fields, but the distinctions are not absolute.

Philosophers of science have maintained that all data are theory-laden, not theory-free. Theoretical assumptions enter the selection, reporting, and interpretation of what are taken to be data. Moreover, theories do not arise from logical analysis of data but from acts of creative imagination in which metaphors and analogies often play a role. Models help one imagine what is not directly observable, especially in the realm of the very large (astronomy) and the very small (quantum physics). In the case of religion such data as religious experience, rituals, and scriptural texts are even more heavily laden with human interpretation. In religious language, metaphors and models are even more prominent.

The term *paradigm* was used by Thomas Kuhn to refer to a cluster of conceptual, metaphysical, and methodological presuppositions embodied in a tradition of scientific work. With a new paradigm the old data are reinterpreted and seen in new ways, and new kinds of data are sought. An established paradigm is resistant to falsification, since discrepancies between theory and data can be set aside as anomalies or reconciled by introducing ad hoc hypotheses. Religious traditions can also be regarded as communities that share a common paradigm. Their interpretation of data (such as religious experience and historical events) is even more paradigm-dependent and resistant to falsification, but it is not totally immune to challenge.

Many authors have also explored conceptual parallels between particular scientific and religious ideas. Recent discussion of human nature has drawn from both theology and science. The dualism of body and soul in classical Christianity has been questioned by theologians who find in the Bible itself a more integral view of the person as an embodied unity of thinking, feeling, and acting. Some scientists, on the other hand, have challenged reductionism and look on the person as a multileveled psychosomatic unity. Neuroscientists studying the brain have found that emotional as well as rational capacities are important in human life, as the biblical tradition has long maintained. The social character of selfhood is a theme common to biblical thought and research in cognitive psychology and anthropology.

Parallels between the holism of quantum physics and the holism of Eastern mysticism have often been noted. The quantum description of an atomic system must be given for the whole system, which cannot be analyzed as the sum of its separate parts. Nonlocal connections are evident in experiments in which two particles originating in a single event continue to be entangled with each other when they reach widely separated detectors. The physicist David Bohm and in a more popular vein, Fritof Capra, have seen a striking similarity between quantum holism and the experience of undifferentiated oneness encountered in the depth of meditation. In quantum physics the observer and the observed are inseparable; so, too, the mystic tradition speaks of the union of subject and object. Because these writings stress personal experience and the limitations of human knowledge, they can be considered as forms of Dialogue, but in their more systematic and metaphysical elaboration they might be considered as examples of Integration.

Integration

Advocates of Integration call for reformulations of traditional theological ideas that are more extensive and systematic than those envisaged by advocates of Dialogue. In natural theology it is claimed that the existence of God can be inferred from (or is supported by) the evidence of design in nature. In a theology of nature, the main sources of theology lie outside science, but scientific theories strongly affect the reformulation of certain doctrines. In a systematic synthesis, both science and religion contribute to the development of an inclusive metaphysics, such as that of process philosophy.

Natural theology. The medieval theologian Thomas Aquinas held that some of God's characteristics can be known only from revelation in scripture, but the existence of God can be known by reason alone. His teleological argument (from *telos,* Greek for purpose or goal) starts from orderliness and intelligibility as general characteristics of nature, but he goes on to cite specific evidence of design in nature. Scientists in the seventeenth century, including Isaac Newton and Robert Boyle, saw God's hand in the details of natural systems from the structures of animals to the solar system. In the early nineteenth century, an Anglican priest, William Paley, said that if one finds a watch on a heath one is justified in concluding that it was designed by an intelligent being; if in the eye many complex parts function together to achieve a single end, it, too must have had a designer. Darwin dealt a serious blow to the traditional design argument, for he showed that adaptation can be explained by random variation and natural selection. But Darwin himself accepted a revised version of the argument; he said that God did not design the particular details of individual species, but designed the laws of evolutionary processes through which the species were formed, leaving the details to chance.

Traditionally, design referred to the execution of a detailed preexisting plan. But chance seems to have played a large role in evolutionary history. Mutations are random and the overwhelming majority are harmful. Some changes were the product of contingent circumstances, such as the comet that was probably responsible for the extinction of the dinosaurs. Yet evolutionary history dos show an overall trend toward greater responsiveness and awareness. The capacity to gather, store, and process information has steadily increased. Design can now be identified with an open-ended direction of change rather than with an exactly specified end product.

The Anthropic Principle in writing by contemporary cosmologists can be interpreted as a new form of design argument. The fundamental parameters of the early universe seem to be fine-tuned for the conditions needed for the emergence of life and intelligence. If the expansion rate one second after the Big Bang had been smaller by even one part in a hundred thousand million million, the universe would have recollapsed before evolution could have occurred. If the expansion had been even a tiny fraction faster it would have dispersed too rapidly for galaxies and planets to have formed. The universe seems to be balanced on a knife-edge, too improbable to be a fortunate chance occurrence.

Most defenders of natural theology, such as Paul Davies, do not claim to offer proofs for the existence of God, but argue that a cosmic designer who does not intervene is a more plausible ultimate explanation than naturalistic alternatives. Some proponents of a modest natural theology combine it with adherence to a theistic religious tradition. But critics point out that in itself natural theology leads only to the God of deism who started the universe and was inactive thereafter, not to the God of theism who is actively involved in the world.

Theology of nature. A theology of nature does not start from science, as natural theology usually does. Instead, it starts from a religious tradition based on religious experience and historical revelation. But it holds that some traditional doctrines need to be reformulated in the light of current science. Here science and religion are considered to be relatively independent sources of ideas, but with some areas of overlap in their claims. An extensive literature has addressed the question: How could God act in the world described by the laws of science without intervening supernaturally and discontinuously?

Our understanding of the general characteristics of nature will affect our models of God's relation to nature. In contemporary views, nature is understood to be a dynamic evolutionary process with a long history of emergent novelty, characterized throughout by both law and chance. The natural order is ecological, interdependent, and multileveled. These characteristics will modify our representation of the relation of both God and humanity to nonhuman nature. This will, in turn, affect our attitudes toward nature and will have practical implications for environmental ethics. The problem of evil will also be viewed differently in an evolutionary rather than a static world.

For the biochemist and theologian Arthur Peacocke the starting point of theological reflection is past and present religious experience in an ongoing religious community. But Peacocke is willing to reformulate traditional beliefs in response to current science. He discusses at length how chance and law work together in cosmology, quantum physics, nonequilibrium thermodynamics, and biological evolution. He gives chance a positive role in the exploration of potentialities at all levels. Peacocke describes the emergence of distinctive forms of activity at higher levels of complexity in the multilayered hierarchy of organic life and mind.

God creates through the whole process, not by intervening in gaps in the process. Peacocke defends the idea of top-down causality within organisms and goes on to speak of God as a top-down cause.

Another proposal starts from the indeterminacy of quantum theory. In contrast to the determinism of classical physics, quantum physics gives only a range of probabilities rather than exact values in predicting individual events in subatomic systems. Some physicists think this unpredictability is attributable to the limitations of current quantum theory. But most physicists hold that indeterminacy is a property of the atomic world itself. Physicist and theologian Robert John Russell has argued that if quantum events are not completely determined by the laws of physics, the final determination could be made by God. God would not have to intervene to alter a determinate state, but would actualize one of the multiple potentialities present, all of which have identical energy, so that no input of energy would be required. In many situations indeterminacies at the atomic level average out to give predictable behavior for larger groups of atoms. But in some cases very small differences can be greatly amplified. A genetic mutation could change the course of evolutionary history. Where science finds only chance, the theist can see providential guidance. Traditionalist critics of such views hold that by representing God's action as a subtle influence that is not scientifically detectable, rather than as a more dramatic supernatural intervention, these authors have accommodated too much to science.

Systematic synthesis. A more systematic integration can occur if both science and religion contribute to a coherent world view elaborated in a comprehensive metaphysics. Metaphysics is the province of the philosopher rather than of the scientist or the theologian, but it can serve as an arena of common reflection. In the thirteenth century, Thomas Aquinas articulated an impressive metaphysics that has remained influential in Catholic thought. His voluminous writings systematically integrated ideas from earlier Christian authors with the best philosophy and science of his day, derived largely from the works of Aristotle.

The process philosophy of Alfred North Whitehead and his followers is a promising candidate for a mediating role today. Whitehead was familiar with quantum physics and its portrayal of reality as a series of momentary events and interpenetrating fields rather than separate particles. For him, as for evolutionary thinkers, nature is a dynamic web of interconnected events, characterized by novelty as well as order. Process thought holds that the basic constituents of reality are not two kinds of enduring entity (mind/matter dualism) or one kind of enduring entity (materialism), but one kind of event with two aspects or phases. All integrated events have an inner and an outer reality, but these take very different forms at different levels. Viewed from within, interiority can be construed as a moment of experience, though conscious experience occurs only at high levels of organization.

According to process philosophy, God elicits the self-creation of individual entities, thereby allowing for freedom and novelty as well as order and structure. Process thinkers reject the idea of divine omnipotence; they portray a God of persuasion rather than coercion, and they have provided distinctive analyses of the place of chance, human freedom, evil, and suffering in the world. Christian process theologians such as John Haught point out that the power of love, as exemplified in the cross, is precisely its ability to evoke a response while respecting the integrity of other beings. The thought of Jesuit paleontologist Pierre Teilhard de Chardin shows some similarities with process theology, including affirmation of an evolutionary cosmos and postulation of interiority in all beings, though his approach is less philosophical and more poetic—and sometimes more mystical—than that of authors indebted to Whitehead.

Process theology has been criticized for departing too far from classical Christianity. It does emphasize divine immanence (without excluding transcendence), whereas classical Christianity emphasized transcendence. More philosophers have abandoned the search for a unifying metaphysics, though there has been some revival of interest in questions once dismissed as metaphysical. The majority of authors who want to move beyond Conflict and Independence hold that we will have to be content with Dialogue or with less philosophical forms of Integration.

See also CHRISTIANITY; INTELLIGENT DESIGN; SCIENCE AND RELIGION, HISTORY OF THE FIELD

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IAN BARBOUR

SCIENCE AND RELIGION, PERIODICAL LITERATURE

Every major field of human discourse spawns a literature proportional to the intensity of the conversation. Science and religion is no exception. Fascinating topics, historic and contemporary, have arisen at the intersection of these two very different fields, and a periodical literature has emerged, both to facilitate communication among scholars who have entered into this conversation, and to report the conversation to a larger audience.

Given the diversity within science and among religions, it is no surprise that the field's periodicals address the disciplines differently. In some journals *religion* means *theology,* and the editorial approach is primarily theoretical. Some periodicals intend *religion* to include all world religions, whereas others intend it as a synonym for a particular brand of faith. Still other publications address issues of applied religion, meaning spirituality or public morality, and applied science, such as medicine, politics, or economics.

The field's most scholarly journal is the quarterly *Zygon: Journal of Religion and Science,* founded in 1965. *Zygon* has three sponsors: the Institute for Religion in an Age of Science (IRAS), the Center for Advanced Study in Religion and Science (CASIRAS), and Rollins College in Winter Park, Florida. *Zygon* construes religion broadly as anything that relates to the human quest for purpose and the journal has an exceptionally broad base of scholarly contributions.

The Center for Theology and the Natural Sciences (CTNS) in Berkeley, California, launched a new journal, *Theology and Science,* in 2003, with an intellectual focus on Christian theology. This journal is the continuation of the quarterly *CTNS Bulletin,* founded in 1982. Animated and enduring conversations have arisen within the Christian evangelical camp, which continues to debate vigorously the truth and significance of Darwinism. The most substantial journal in this category is the quarterly *Perspectives on Science and Christian*

Faith, the official journal of the American Scientific Affiliation (ASA), which serves about 2,500 readers. Founded in 1941, the ASA and its journal promote the idea that both the Bible and science are revelations from God. Most of the articles relate to the creation-evolution controversy, and the journal has become a primary vehicle for the critical discussion of theistic evolution and Intelligent Design. A more conservative journal, *Origins and Design,* founded in 1980 and published by the Access Research Network, is devoted almost exclusively to the promotion of Intelligent Design. The quarterly glossy magazine, *Facts and Faith,* founded in 1987 (now discontinued), had almost seven thousand paid subscribers, and was published by the apologetics organization Reasons to Believe. It used design arguments to bolster faith in the Bible.

A number of fundamentalist publications promote a more conservative, biblically literalist view of science and religion. Two of the most influential are *Acts and Facts,* founded in 1971, a free monthly newsletter sponsored by the Institute for Creation Research in Santee, California, and *Creation Magazine,* founded in 1978, a more populist and politically oriented publication published by the Back to Genesis group.

Reports of the National Center for Science Education is a bimonthly newsletter founded in 1980 that reaches more than four thousand readers with articles and resources to refute creationism. These journals reflect America's ongoing struggle with Darwinism.

Outside of the United States, the science and religion conversation is much less intense but no less diverse. The ambitious semiannual journal *Science and Christian Belief* is the product of two organizations based in Britain. The Victoria Institute, founded in 1865 as the first anti-evolution group, merged its journal in 1989 with that of Christians in Science. The resulting journal, launched in 1988, resembles ASA's *Perspectives,* though it has a more scholarly and theologically eclectic approach. Given the journal's British roots, the editorial bent leans less toward the creation-evolution controversy, which is primarily an American phenomenon.

Other European science and religion publications include the twice-yearly book review compendium *Reviews,* founded in 1983 and published by the British Science and Religion Forum. The European Society for the Study of Science and Theology (ESSSAT) publishes two biennial texts: *Issues in Science and Theology* (2000) and *Studies in Science and Theology* (1987), which are basically book series.

In India, the Muslim Association for the Advancement of Science publishes the *Journal of Islamic Science,* founded in 1984, which looks at the historical and philosophical questions raised by science from an Islamic perspective. The *South African Science and Religion Forum,* founded in 1993, is a newsletter that reaches about five hundred readers, published by the Research Institute for Theology and Religion at the University of South Africa.

Two web sites, *Metanexus* and *Counterbalance,* span the geographic borders of science and religion and provide timely, comprehensive internet resources. *Metanexus* was launched in 1998 and by 2002 had thousands of subscribers in nearly sixty countries. It operates several electronic list servers that disseminate news updates daily and it publishes a monthly email newsletter. Since 1996, *Counterbalance* has provided a tightly woven web of materials that encapsulate the discussions taking place in the science and religion field, including such resources as video clips of lectures.

There are also two popular publications that support the field of science and religion: *Science and Spirit* is a bimonthly glossy magazine, and *Research News and Opportunities in Science and Theology* is a monthly newspaper. *Science and Spirit,* launched in 1989 and repositioned in 2001 for a general audience, explores the religious dimensions of scientific discoveries and technological advances. Brief, timely, articles by well-known thinkers illuminate the nexus of science and spirituality, while incorporating the wisdom of a world of faiths. Paid subscribers exceeded nine thousand in 2002. *Research News and Opportunities in Science and Theology* was launched in 2000 as a general clearinghouse of information for the field of science and religion. This monthly paper reports on the science and religion community's activities, organizations, and opinion leaders, and it publishes book reviews and interviews that address emerging and established topics of scientific and religious inquiry. *Research News* also serves the former readership of *Bridgebuilding* and *Progress in Theology,* two small specialized publications disbanded in 2000. *Research News, in 2002,* had a paid circulation over five thousand and readership of about thirty thousand.

Beyond the established scholarly periodicals and the emerging popular ones are a number of newsletters that, while connected to specific science and religion centers, often contain articles and reviews of general interest. Some of the more significant are *The Pascal Centre Notebook* from the Pascal Centre for Advanced Studies in Science and Faith at Redeemer College in Ancaster, Ontario; *Science and Religion Forum* from the Institute on Religion in an Age of Science (IRAS); and the *Journal of the Faith and Science Exchange,* published by the Boston Theological Institute.

See also SCIENCE AND RELIGION IN PUBLIC COMMUNICATION

KARL GIBERSON

SCIENCE AND RELIGION, RESEARCH IN

It is essential to begin by noting that research in science and religion covers a wide range of exploration. The frequent use of the terms "science-and-religion field" and "science-religion debate" tends to obscure not only the range of relationships between different sciences and different religions, but also different approaches to researching these relationships. There is a diverse matrix of relationships between the cognitive claims of different sciences and different religions. As argued by Willem B. Drees in *Religion, Science, and Naturalism* (1996), religions have different aspects, which have different relations to the science under consideration, and the phenomenon of religion is itself a proper object of scientific study. But the matrix is yet broader and more intricate than that—sciences do not consist only of propositional claims being tested by experiment, but of communities of individual scholars whose work is informed both by their individual spiritual attitudes and by the ethos of their community. That ethos is in turn informed by social, cultural, and political factors.

Some historical considerations

That the matrix of relationships mentioned above has been in constant shift throughout the last few hundred years has been an emphasis in the work of historians such as John Hedley Brooke. Brooke's determined insistence that, viewed historically, the unfolding of these relationships is often more surprising and paradoxical than might have been supposed has been a significant counter to the devising of overly simplistic grand narratives of *the* relationship between science and religion. In Brooke's book with Geoffrey Cantor, *Reconstructing Nature* (1998), he explores the range of approaches by which history can enrich and subvert trite preconceptions, and includes a fascinating chapter on chemistry, a subject too often omitted from historical surveys of the science-religion matrix.

A problem that will continue to beset historical research in science and religion is: What was it about European Renaissance Christendom that particularly predisposed it to give rise to modern Western science? Important markers in this debate have been Reijer Hooykaas's stress on the importance of Protestantism, Stanley Jaki's emphasis on the contribution of Catholic thinking, and Amos Funkenstein's important *Theology and the Scientific Imagination from the Middle Ages to the Seventeenth Century* (1986). The question can be put another way: How can we account for the "failure of early science," as Philip Luscombe puts it in *Groundwork of Science and Religion* (2000)? Neither Ancient Greek culture, nor the "Golden Age of Islam" in the tenth and eleventh centuries, nor indeed Chinese or Indian civilization, gave rise to any expansion of experimental enquiry and technological development that remotely parallels that of the modern West. This question will need particularly sensitive handling in the twenty-first century, when religious conviction and political and economic aspiration have become so evidently intertangled with the question of what is a truth to be lived by.

The character of the science-religion debate

The apparent unity of the science-religion debate in the Western world has had much to do with two particular dynamics. First, certain prominent scientists continue to make assertions about the reach of science, claiming that in some way it falsifies the truth-claims of religion. Names that come to mind include Stephen Hawking and Peter Atkins (in their different ways) in respect of physics, and Edward O. Wilson and Richard Dawkins (again in their different ways) in respect of biology. These assertions tap into a perception in the public mind that indeed religion is in headlong retreat before science. People therefore seek overviews of how this supposed battle is going, overviews which have been provided with consistent distinction over many years by the Minnesota-based philosopher and theologian Ian Barbour, whose typologies of possible relationships between the disciplines—in terms of conflict, independence, dialogue, and integration—have done so much to put the "conflict" hypothesis in perspective.

The second ingredient tending to promote a sense of the unity of the field is the eloquent and sustained contribution made since the 1970s by four scholars in particular. Barbour has already been mentioned. His name is often linked with those of the British scientist-theologians Arthur Peacocke and John Polkinghorne, but the contribution of the American philosopher Holmes Rolston III has been of comparable stature. All emerged from a background in hard sciences—Peacocke in physical biochemistry, the other three in physics itself. All have surveyed the relationship between sciences and religions as being a unity; all have explicitly taken issue with the "falsifiers" mentioned above. Though they differ in the degree of their debt to process philosophy, and in their theological inclinations, all remain deeply committed to a critical-realist view of human enquiry. Science finds things out; over time, it tells us more and more about the world. Science is therefore an ally in enquiring more faithfully into the creativity of God. Theology too is a realist discipline; over time, it can expect to rid itself of formulations that are not coherent with other robust understandings of the world and of ourselves. For all four, in their different ways, Christian monotheism is at the cutting-edge of this exploration.

The relationship of ecological theology to science-religion research

For far too long ecological theology has lived in a separate ghetto from what is usually thought of as research into science-and-religion. It is interesting to consider why this might have been so. "Scientist-theologians" (as Barbour, Peacocke, and Polkinghorne were dubbed in Polkinghorne's comparative study *Scientists as Theologians* [1996]) all take an essentially positive view of science and seek to learn how theology in the Christian tradition might resemble it. Much ecological thinking, however, has reflected on how the discoveries of science have been used to develop technologies that oppress and destroy nature—also on how patriarchal monotheism has seemed to be an ally of that oppression, and in parallel also of the oppression of women. Ecological theology, then, has been the home not, typically, of the celebration of science but of suspicious readings of the texts of power—scientific as well as scriptural. It has also been a domain of remythologizations: for example, the universe as the body of God as in Sallie McFague's *The Body of God* (1993); the planet Earth (Gaia) as the sacred space on which human beings depend as in Anne Primavesi's *Sacred Gaia* (2000).

Barbour has written extensively on the ethics of technology, but it is Rolston who has been a key figure in this uneasy relationship, since he has made significant contributions both on science-and-religion and in environmental ethics. He has carefully analyzed how value is intrinsic to all living things and the systems within which they function, but he has also insisted that a practical approach to environmentalism must insist on an element of philosophical realism. Science is not only a vital diagnostic aid as to the extent of the environmental crisis because it does tell us things about the way the world is; it is also a source of potential solutions. There is much work to do to widen the bridge Rolston has begun to build.

The divine action debate

Central in the divine action debate has been the contribution made by six Vatican Conferences on science and theology held between 1987 and 2000, the first subtitled "A Common Quest for Understanding" and the last five "Scientific Perspectives on Divine Action." All the proceedings have been edited by Robert John Russell and colleagues (1988, 1993, 1995, 1998, 1999, 2001). The debate about God's providential activity and how it might be related to the story of the universe has been the biggest single engine driving research in science and theology in this period. At two poles of the debate have been (1) the Thomist understanding of "double agency," according to which God's primary agency lies behind each and every event, but God's providence operates through secondary causes, such as human activity, the stress being on the ultimate sovereignty of God; and (2) the process-theological view that divine persuasion is an ingredient of every event, luring entities toward harmony and creativity, but never determining outcomes. Here the stress is on God the fellow-suffering persuader. Neither of these positions in itself makes for easy conversation with the sciences.

Important markers in the effort to understand divine action within a scientifically described universe include (1) the proposal, going back to William Pollard in the 1950s, but further developed in particular by Russell and the South African physicist George F. R. Ellis, that quantum indeterminacy provides the "gap" in which God can act undetectably on the physical universe; (2) Polkinghorne's provocative assertion in his *Science and Providence* (1989) that we should look for the locus of God's action in the openness and indeterminacy of the universe at the macroscopic level, as illustrated by the equations of chaos theory; (3) Peacocke's insistence on the importance of "top-down causation," later "whole-part influence"; and (4) Nancey Murphy's masterly assessment of these views, which can be found in the Vatican Conference proceedings published as *Chaos and Complexity* (1995). The divine action conferences have covered physics and cosmology, chaos theory, evolutionary and molecular biology, and neuroscience. These subjects will be touched on further below. The current state of the argument on quantum indeterminacy is summarized in the Vatican Conference proceedings entitled *Quantum Mechanics* (2001).

The Vatican Conferences have been invaluable conversations among eminent thinkers, and essential resources for research students. However, the overall conclusion from the debate must be that efforts to press too closely the question of God's action, to allow the relevant science to frame too closely how that action might be formulated, have consistently failed. Polkinghorne, the most ambitious thinker in this area, retreated in books such as *Belief in God in an Age of Science* (1998) into much more theological and less physical formulations.

One of the key theological issues underlying the debate is that of God's relation to time. Again this sharply divides the classical Thomist approach, which places God beyond time, from process-influenced schemes. The relation of this debate to understanding of time in physics is much debated. Polkinghorne has insisted that an omnipresent God can be in time but equally present to every point in space. Drees has objected that relativistic understandings of space-time permit no such vantage point.

Another key issue is that of divine kenosis—self-emptying. Two meetings of senior scholars on this topic in 1998 and 1999 led to an important series of essays, *The Work of Love (2001)*, edited by Polkinghorne. Does God's creative activity involve an element of self-limitation, reaching a climax (for Christians) at the Incarnation and Passion of Christ? A particular importance of these meetings was that they not only brought together the four senior figures in the debate—Barbour, Peacocke, Polkinghorne, and Rolston—but also a major philosopher of religion, Keith Ward, and eminent figures from the rest of the theological world, including Jürgen Moltmann, Paul Fiddes, and Sarah Coakley. It is vital to the future of explorations in this interdisciplinary area that research does not remain confined within its own little interest group, but hears from and responds to other branches of theology.

The contribution of philosophy of science

Research in science and religion necessarily involves asking what sort of enterprise is the science in question? Reference to the philosophy of science, however, is complicated by the fact that most practicing scientists would not recognize the descriptions of their activity offered by most contemporary philosophy. Philosophers, working in the context of postmodern critiques of foundationalism, and with a profound awareness of the cultural embeddedness of all descriptions, tend to stress the practice of science as the activity of a particular community, a particular type of rational enterprise. Most scientists simply think of themselves as finding out more about the way things really are. This is no doubt why the thinkers who have done most to develop theological conversation with working scientists have tended to espouse a fairly strong form of critical realism. Significant support for critical realism, particularly with respect to science, has come from Ernan McMullin; an even more robust insistence on realism can be found in Roger Trigg's *Rationality and Religion* (1998).

Among the philosophers who have most engaged with the challenge of postmodernism, it is important to mention the work of Murphy and of J. Wentzel van Huyssteen. Murphy made a bold bridge from the methodology of science into theology in her *Theology in the Age of Scientific Reasoning* (1990), using the model of core and auxiliary hypotheses developed by Imre Lakatos. In the process, she rejected critical realism in theology on the grounds that it makes too great a claim as to our knowledge of elements of reality beyond our ordinary human ways of knowing. Since then, Murphy has worked with Ellis to develop a model in which cosmology might inform ethics, as in their *On the Moral Nature of the Universe* (1996).

In contrast to Murphy, van Huyssteen wants to defend "a weak form of critical realism," essentially as an inference from the evolved capacity of human beings to make sense of the cosmos. He has made a telling diagnosis of the predicament of contemporary theology as being, in a sense, between a rock and a soft place, between the strong progressivist truth-claims of science and postmodernity's relativizing suspicion of all grand narratives. Yet van Huyssteen asserts that this makes the conversation between science and theology a particularly important one. As he claims in *The Shaping of Rationality* (1999), if any rational communities are to be in conversation, it should be these two.

The conversation with the physicists

This conversation is best known through the works of the Australia-based British physicist Paul Davies, in particular *God and the New Physics* (1983) and *The Mind of God* (1992). Davies is a fascinating example of a physicist of no particular religious affiliation whose explorations of the lawfulness and fruitfulness of the cosmos draw him to God-language. It led him in his early days to postulate that there are senses in which science may teach us more about God than religion can; later he was disposed to remark not only on the astonishing intelligibility of the universe but also on the limits of human understanding—the laws of nature will not of themselves answer every question about existence. Interestingly, Davies has also explored the theologically intriguing question as to whether life on Earth may have extraterrestrial origins.

Two arguments at the boundary of physics and metaphysics currently generate a lot of energy and lead to a great deal of God-talk, if not always of the most informed or nuanced kind. The first concerns the so-called anthropic coincidences. If certain fundamental constants were even minutely different, or if the early history of the universe had unfolded even slightly differently, this universe could not be fruitful of life. So, did God fine-tune the cosmos? This is a discussion dogged by imprecision of terms and by the temptation to try and resolve a metaphysical issue by argument in physics (a mistake against which Polkinghorne has consistently argued). The main alternative to divine fine-tuning is the many-universes theory, and neither alternative is subject to physical test. However, it must be admitted that developments in theoretical physics, in particular those concerning the possibility of universes giving rise to other universes (see for example Lee Smolin's *The Life of the Cosmos* [1997], for a different approach see Hawking's *The Universe in a Nutshell* [2001]) could influence the balance of the argument, though they could not settle it. A change in the balance would be a change in the apparent consonance between the picture physical science offers and the notion of a God designing the universe. If the universe as described by science looks unique and precisely fine-tuned for life, the consonance is high. If this looks like one of many trillion universes constantly budding off from one another, the anthropic coincidences look less suggestive, and consonance is lower. *Consonance* is a felicitous term, first developed by McMullin and further explored by Ted Peters, for describing the way scientific and theological formulations seem sometimes to come into harmony. But apparent consonances come and go; mature interdisciplinary research in this area requires that they not be too much relied upon.

This is nowhere more important than in the other major area of debate between physics and philosophical theism—the question of the origin and cause of the universe. The enthusiasm of Pope Pius XII for the apparent consonance between early Big Bang cosmology and Genesis 1 has long been subverted by a series of alternative proposals in physics. The Big Bang model continues as a description of the development of the universe, including its apparent rapid early inflation. However, various models of the origin of the universe and its very early growth, in a context in which quantum effects may have dominated, now suggest that the arising of this fourteen-billion-year-old universe, containing a hundred billion galaxies, may have been some form of chance fluctuation in a preexisting state of zero net energy. This has been taken by some to challenge both the Christian doctrine of creation-out-of-nothing (*creatio ex nihilo*) and the notion of "God's moment" before the laws of physics took effect. However, more rigorous thinking shows that the "nothing" of the quantum vacuum is a highly structured state, hardly *nihil* in theological terms. Robert John Russell's analysis, published in *Religion and Science: History, Method, Dialogue* (edited by W. Mark Richardson and Wesley J. Wildman, 1996), shows that a discrete temporal moment of becoming would be an interesting consonance with Genesis but is not necessary to a Christian theology of creation.

Russell has also remarked that accounts of the end of the universe will necessarily exhibit a dissonance between scientific prediction and Christian formulation. All the different scientific accounts suggest that this universe will have a finite lifespan, and even if new universes bud off from it or are born out of it, there seems little likelihood that structure or information, let alone living things, could survive such a transition. The Christian hope, however, anticipates a new creation and a continued bodily existence of persons. Perhaps because of this dissonance there has been surprisingly little work in this area of the science-religion debate. Some interesting new science continues to emerge (for a summary see Martin Rees' *Our Cosmic Habitat* [2002]), but few theologians have explored the territory, honorable exceptions being Polkinghorne and Welker's edited work *The Ends of the World and the Ends of God* (2000) and Arnold Benz's *The Future of the Universe* (2000).

Theology and biology

In 1996, Holmes Rolston contributed an interesting essay entitled "Science, Religion and the Future" to Richardson and Wildman's *Religion and Science.* In it he remarks that "Outspokenly monotheistic biologists are as rare as those who think physics is compatible with monotheisms are common" (p. 65). There is a contrast between the tone of mutual curiosity in much of the conversation between philosophical theism and physics and the often acrimonious conversation between theologians and certain biologists, particularly Dawkins, Wilson, and Lewis Wolpert. It may be argued that Dawkins has had his uses in stirring up the debate, as Jacques Monod did before him. Strongly reductionist denials of the significance of human existence and humans' search for God did much to provoke Peacocke's long engagement with theology's relation to evolutionary biology, as summarized in his *Paths from Science towards God* (2001). The British philosopher Mary Midgley has also been important for her rejection of trite reductionism, and her insistence that there can be many "maps" of the character of existence and that these maps are not mutually exclusive, that mortgages are in a sense as real as membranes or muons.

However, too much adversarial writing sometimes distracts theologians from their central task. The long battle, especially in the United States, over creationism has distracted attention from the fascinating questions that arise if a generally Darwinian picture is accepted. Two questions particularly come to mind.

First, when and how did evolving hominids develop the status Christian theology accords humans as being in the image and likeness of God? When did they develop the capacity for worship, and what view of the world did this early religious practice reflect? Beyond the oft-repeated statement, much insisted on by Peacocke, that theology must discard a picture of a historical fall from a preparadisal state, little progress has been made in this area. Perhaps theologians are right to be cautious, since the paleontological evidence changes continually and seems to push the development of artistic and symbolic skills further and further back in time.

Many of the details of the second question were already known to Charles Darwin by the mid-1800s. It concerns the theodicy problem raised by evolution through natural selection. How could a loving God use a process so replete in casualties—individual organisms that never grow to their potential or die in horrible pain, species that go extinct—to realize other ends, such as the evolution of humans? Again, scientist-theologians need to learn from ecotheologians and move beyond the very anthropocentric ambit of theodicy as it has tended to be done. Some early evolutionary theodicies can be seen in Ruth Page's *God and the Web of Creation* (1996), John Haught's *God After Darwin* (2000), and Christopher Southgate's "God and Evolutionary Evil" (2002).

One of the most intense areas of ethical debate in the early twenty-first century is the area of genetic manipulation and cloning. This focuses questions as to the role and status of the human person. Are we "plain citizens of the biotic community" as Aldo Leopold stated, or the "created co-creators" (suggested by Philip Hefner in *The Human Factor* (1993)? Issues of genetic reductionism also stalk the debate—to what extent do we understand an organism by understanding the location and function of its genes? Ted Peters has made an interesting move here, arguing in *Playing God?* (1997) that much of the opposition to genetic technologies is itself reductionist. Celia Deane-Drummond in her survey *Biology and Theology Today* (2001) insists that the missing ingredient in the debate is an appeal to wisdom, a promising route by which Christian theology might inform this branch of ethics.

A further question, still embryonic, is to what extent work on chaos and complexity theory, the self-organizing behavior of systems such as those that gave rise to and nurtured life on Earth, may alter our perspective on the evolutionary history of the biosphere. The Danish scholar Niels Gregersen has been at work on the significance of autopoiesis in ways which may bear rich fruit in addressing questions of the "designedness" of the biosphere and the theology of God's interaction with evolving life.

Theology and psychology

This conversation between theology and psychology promises to be a great growth area in the first half of the twenty-first century. As Philip Clayton has noted in his *God and Contemporary Science* (1997), human agency is the best analogy, however weak it may be, to the agency of a personal God. It is therefore of the first importance that theologians track research into the psychology of agency. Secondly, religious experience (a particular research interest of Fraser Watts, the Starbridge Lecturer at Cambridge) is properly the subject of both theological and scientific investigation. Thirdly, our view of the attributes of human personhood has historically been profoundly influenced by theological formulations. In Christian societies this has often been expressed in terms of "soul" language. Yet in contemporary Western society it is science that principally informs ethical and legal judgments as to when personhood begins and ends. Hence the special significance of the project involving Warren Brown, Nancey Murphy, and H. Newton Maloney, helped by (among others) a distinguished evolutionary biologist in Francisco Ayala and an eminent neuroscientist in Malcolm Jeeves. This led to the book *Whatever Happened to the Soul?* (1999), in which the authors explore a nonreductive physicalist model of the mind-brain relation. On this model, soul language becomes adjectival, not in any way an assertion that some sort of separate entity exists within each human which carries the spiritual life of the person. The ethical implications of such a model are still to be worked out, though John Habgood's gradualist model of the beginning and end of personhood in his *Being a Person* (1998) is a challenging starting point, particularly in relation to terminal illness, dementia, and persistent vegetative state.

Religions other than Christianity

There are good, if hotly debated, reasons why Christian theologians have led the debate on the relationship of theology to Western sciences. However, the science-religion debate must not consist solely of a retelling of some Christian story that Christendom fostered modern science, made a brief mistake with Galileo, survived the assaults of atheism and Darwinism, and now flourishes as a trendy partner to contemporary cosmology. It is self-evident that science's relationships with religions and theologies other than the Christian are not only important in themselves but may supply wholly new perspectives from which to understand interdisciplinary conversation of this type.

The Christian theologian must not seek to mold other traditions into the particular thought-patterns that happen to have informed the debate between sciences and textual, critically aware Christian theology. However, long established questions are bound to occur to that theologian such as (1) does the radical monotheism of Islam, with its great emphasis on the authority of the literal text of the Qur'an, provide a climate for conversation with the forms of knowledge offered by various sciences; and (2) can the apparently non-realist attitude to matter in much Eastern thought be reconciled with a realist cosmology?

The answer to these questions needs much further exploration. Recent accounts by practicing Muslims who are scientists, such as Mehdi Golshani and Bruno Guiderdoni in Richardson and Slack's *Faith in Science* (2001), suggest that science can be regarded as worship, as responding to the Qur'anic command to see Allah's signs in the universe, yet there is no question that for many Islamic thinkers a theory such as Darwinian evolution is profoundly unpalatable. As Michael Robert Negus relates in the textbook *God, Humanity, and the Cosmos* (1999, edited by Southgate), two of the approaches in K. A. Wood's classification of ways to account for the sciences as compatible with

Islam—compartmentalism and a phenomenological approach to scriptural texts—would seem to show promise in encouraging distinguished Muslim scientists and theologians in the integration of contemporary science with an Islamic metaphysics. The third approach, scientific exegesis, seeking to infer scientific truths from the scriptural texts themselves, seems fraught with problems.

As for Eastern thought, it does seem that its apparently nonrealist attitude toward matter can be, up to a point, reconciled with a realist cosmology. An article by Vaharaja V. Raman on Hinduism in *When Worlds Converge* (2002, edited by Matthews, Tucker, and Hefner) suggests that indeed the material world, and scientific conclusions about it, can be taken seriously in Hindu thought, provided there is no suggestion that the descriptions arrived at have objective reference or that they are of parallel importance to the discoveries of the spiritual masters. Points of contact can be noted here with the debate within Christian theology. Likewise an article on Buddhism by Pinit Ratanakul (in the same volume) indicates an openness to the findings of science, as long as the central moral insights of the faith remain preeminent. The Buddhist concepts of nonharming and interdependence remain important resources for developing ecological ethics.

Resources, sponsors, and key organizations

It is enormously challenging to engage with the complex matrix that is the science-religion debate, and books that can function as textbooks for the student remain few. Rolston's *Science and Religion* (1987) was an early example, and Barbour has produced a series of overviews, of which *Religion and Science* (1997) is perhaps the most useful. The first comprehensive, purpose-designed textbook to appear was *God, Humanity, and the Cosmos* (1999), edited by Southgate.

The extraordinary patronage of conversations between science and religion by Sir John Templeton, far and away the biggest single sponsor of this type of research, has done much to build a single community of enquirers. Extensive funding has been made available for the Templeton Foundation's Science and Religion Course Program, which has supported courses in several hundred colleges throughout the world, and other types of workshops and symposia on the classic issues discussed above. An important element in this has been the exploration of the spiritualities of practicing scientists and the effect faith, or lack of it, has on their work.

A couple of centers of excellence in the current debate also deserve mention. Long-term research into profoundly difficult problems—cosmological, theological, and ethical—is conducted with rigor and passion at the Center for Theology and the Natural Sciences in Berkeley, California, under the direction of Robert John Russell. Also important is the Zygon Center for Religion and Science in Chicago, from which Philip Hefner edits *Zygon,* the premier journal in the field. The two most prominent chairs in the field are the James I. McCord Chair in Theology and Science at Princeton Theological Seminary in New Jersey, occupied by J. Wentzel van Huyssteen, and the Andreas Idreos Chair at Oxford University, occupied by John Brooke. The novelist Susan Howatch has endowed another important post at Cambridge University, the Starbridge Lectureship. Europe has the most vigorous society: the European Society of the Study of Science and Theology (ESSSAT), whose biennial meetings are not only a major encouragement to scholars from poorly resourced institutions in Eastern Europe, but profoundly generative in themselves. Extensive information can be found at www.metanexus.net and www.counterbalance.org, which have done much to make current research available online.

Concluding thoughts

The conversations between scientists and theologians that have been discussed above have had a wider impact than might be thought simply by noting the main developments. It is slowly coming to be recognized that it is respectable for those trained in the humanities to know about science. Novels and poems based on scientific ideas and images are now proliferating. Well-known theologians who have specialized in other areas in the past are being drawn into the debate, including, strikingly, the British evangelical scholar Alister McGrath, who published two books on science and religion in 1998. Likewise, eminent scientists are now entering the conversation not, as in the past, to dismiss theology, nor yet to defend it, but to remark on the relationship between disciplines, as in Stephen Jay Gould's model of "nonoverlapping magisteria" in his *Rocks of Ages* (1999). If van Huyssteen is indeed right that the science-theology debate is the paradigmatic case of the possibilities of conversation between two rational communities, these "cross-over" works are of particular significance for the unfolding of human rationality and creativity.

See also SCIENCE AND RELIGION; SCIENCE AND RELIGION, HISTORY OF FIELD; SCIENCE AND RELIGION IN PUBLIC COMMUNICATION; SCIENCE AND RELIGION, METHODOLOGIES; SCIENCE AND RELIGION, MODELS AND RELATIONS; SCIENCE AND RELIGION, PERIODICAL LITERATURE

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CHRISTOPHER SOUTHGATE

SCIENCE FICTION

Science fiction is the genre of stories and film in which a significant element of the plot depends on the laws of mathematics and the physical sciences, or on the use of technology as currently known or as developed in a credible way. Stories in which natural laws are suspended or violated fall into the realm of fantasy rather than science fiction. Most science fiction plots take place in the future, on a fictional planet, or posit the use of a new technology. They explore the best and worst case scenarios that could result from the application of technology or from a variation in the natural world, though remain based on scientific laws as we know them. Though it seems that science fiction is based on science and the material world, most modern works are character based; science fiction explores human life and action within the context of a fictional but possible world. This fictional world allows the author clearly to explore issues in a context that is contrived, thus without the myriad mitigating or confounding factors the real world might present.

The genre of science fiction can be traced back to nineteenth-century novels such as Mary Shelley's *Frankenstein* (1818) and Jules Verne's novels of the 1860s and 1870s (*Journey to the Center of the Earth* and *Twenty Thousand Leagues Under the Sea*). However, the term *science fiction* was not widely used until the 1930s, when a group of pulp fiction magazines featuring stories based on the premises of modern science was established. Beginning with Hugo Gernsback's *Amazing Stories* (after whom the Hugo award in science fiction writing is named), the format was soon copied by several other American and British publications (John Campbell's *Astounding Science Fiction, Science Wonder Stories*). Among writers in Britain, a genre called *scientific romance* grew in the years following World War I with such writers as Olaf Stapledon, J. D. Beresford, H. G. Wells, and Aldous Huxley. In the United States, science fiction remained primarily magazine based until the rapid rise in the production of paperback books in the 1960s, which moved the genre from a predominance of short stories to novels. The science fiction novel emerged as a distinct literary genre in the second half of the century, exemplified in the works of writers such as Isaac Asimov, Ray Bradbury, Arthur C. Clarke, Robert Heinlein, and Kurt Vonnegut.

As the public became sensitized to the effects of science through the dropping of the atomic bomb in 1945, the development of the digital computer, and new advances in biotechnology, science fiction also became a staple for radio (Orson Welles's 1938 radio production of H. G. Wells's *War of the Worlds*), television (*The Jetsons, The Twighlight Zone, Star Trek, The X-Files*), and film plots (Fritz Lang's *Metropolis* [1927], Stanley Kubrick's *Dr. Strangelove* [1964] and *2001: A Space Odyssey* [1968], Ridley Scott's *Blade Runner* [1982] and *Alien* [1979], Steven Spielberg's *E.T.* [1982], and George Lucas's *Star Wars* [1977]). Although science fiction novels continue to be popular and widely published, a larger contemporary audience is reached through film and television, mediums that make it easy for audiences to suspend disbelief and that appeal to our highly visual culture. The plots of science fiction films tend to be more adventure- and special-effects-based and less introspective than the written literature, though there are notable exceptions, such as Kubrick's *2001: A Space Odyssey.*

Popular themes in today's science fiction, regardless of the medium, include intelligent computers or robots, alternative worlds, travel to other planets, encounters with other life forms, the future evolution of the human race, and the ravages of atomic destruction or biochemical warfare. Science fiction has also spawned several subgenres in the late twentieth century, including *cyberpunk,* stories that take place in a virtual world sustained by computers and dominated by multinational corporations (William Gibson's *Neuromancer* [1984] and Scott's film *Blade Runner,* based on Philip K. Dick's *Do Androids Dream of Electric Sheep?* [1968]); *ecoscience fiction,* stories set in either an ecological utopia or distopia (Vonnegut's *Galapagos* [1985], Spielberg's *Jurassic Park* [1993], John Brunner's *The Sheep Look Up* [1972]); and *feminist science fiction* (Ursula K. LeGuin's *Left Hand of Darkness* [1969], James Tiptree's "The Women Men Don't See" [1973] and "The Screwfly Solution" [1977]).

Themes related to religion

The early science fiction pulp magazines were devoted primarily to adventure stories in which the exploration of religious themes or any explicit reference to religion was taboo. However, as science fiction moved into the mediums of novel and film, these strictures fell away. Modern science fiction deals extensively with religion, at times explicitly, at other times through the exploration of metaphysical systems, the nature of humanity or of social structures, the question of mystical powers, or the nature of moral decision making.

A number of science fiction novels have dealt directly with the nature of God. In *A Romance of Two Worlds* (1886), Marie Corelli explores the idea of God as an electrical force. H. G. Wells explores the nature of a finite or an unknowable God in *God the Invisible King* (1917) and *The Undying Fire* (1919). Mary Shelley in *Frankenstein* (1818), one of the earliest books in the science fiction genre, takes as her premise the question of human usurpation of the prerogatives of God. Stories that examine what it feels like to be God or to have godlike powers of omniscience, omnipotence, or the ability to create life forms range from short stories such as Edmond Hamilton's "Fessenden's Worlds" (1937) and Frank Russell's "Hobbyist" (1947), to novels such as Frank Herbert's *The God Makers* (1972) and Stanislav Lem's *Solaris* (1961). The idea of humans who create a god or computers that develop godlike powers is raised in Frederic Brown's "Answer" (1954), Isaac Asimov's "The Last Question" (1956), and Martin Caidin's *The God Machine* (1989). Many stories raise the possibility that a more advanced civilization would seem godlike to human beings. Philip K. Dick explores the question of beings with godlike powers in *Our Friends from Frolix 8* (1970) and the *Three Stigmata of Palmer Eldritch* (1964). Stories that posit an evil or incompetent god include Lester Del Ray's "Evensong" (1967), James Tiptree's *Up the Walls of the World* (1978), and Philip K. Dick's "Faith of Our Fathers" (1980). John Varley questions the basic requirements for being a god in his *Titan* series (1980).

The nature of humankind is so common a theme in science fiction that it has been used as a definition of the genre. Brian Aldiss writes in *Trillion Year Spree: The History of Science Fiction* (1986): "Science fiction is the search for definition of man and his status in the universe which will stand in our advanced but confused state of knowledge (science)" (p. 25). Almost all science fiction works deal implicitly, if not explicitly with the question of what it means to be human. Common plot vehicles include confrontation by an alien race or by intelligent computers, the challenges of disaster or of a dystopian world, and ethical decision making under limited conditions.

The question of not only what human beings are but what we might ultimately become is explicitly dealt with in Olaf Stapledon's *Last and First Men* (1930) and *Star Maker* (1937). Human transformation into a mystical or spiritual form is also examined in Arthur C. Clarke's *Childhood's End* (1953) and *2001: A Space Odyssey* (1968) and Philip Farmer's *To Your Scattered Bodies Go* (1955). The evolutionary ideas of Pierre Teilhard de Chardin are explicitly foundational to George Zebrowski's *The Omega Point* (1972) and appear implicitly in Clarke's *Childhood's End.* Clarke also examines what it means to be human from the perspective of Buddhism in *The Fountains of Paradise* (1979).

A few novels and short stories deal with explicitly Christian themes. The star followed by the magi forms the basis for Arthur C. Clarke's "The Star" (1955). Richard Matheson's "The Traveler" (1952) and Michael Moorcock's *Behold the Man!* (1966) use time travel to examine the crucifixion of Jesus. While these are among the few stories that mention Jesus specifically, a figure whose advent and saving of a culture are messianic in nature is common and can be found in J. D. Beresford's *What Dreams May Come* (1941), L. Ron Hubbard's *Final Blackout* (1940), and Frank Herbert's *Dune* series (1965). The Apocalypse and the second coming of Christ have also formed a backdrop for much science fiction. C. S. Lewis wrote a trilogy in the form of science fiction that moves from a retelling of the story of the garden of Eden to the days before the second coming of Christ in which Merlin plays the role of messiah (*Out of the Silent Planet* [1938], *Perelandra* [1943], and *That Hideous Strength* [1946]). Walter Miller's, *A Canticle for Leibowitz* [1959] and Vonnegut's *Cat's Cradle* [1963] continue the apocalyptic theme, examining human behavior and the role of the church in worlds that have been or are being largely destroyed.

A number of science fiction novels posit a future theocracy, generally in a negative light. This is a particularly strong theme in feminist science fiction, and societies based on a version of Christian or Islamic fundamentalism are found in Margaret Atwood's *The Handmaid's Tale* (1986), Marion Zimmer Bradley's *The Shattered Chain* (1983), Sylvia Engdahl's *This Star Shall Abide* (1972) and Sheri Tepper's *Grass* (1990), *The Fresco* (2000), and *The Visitor* (2002). Feminist science fiction has also explored societies that follow a goddess based religion, a theme in Elizabeth Hand's *Walking the Moon* (1996), Starhawk's *The Fifth Sacred Thing* (1993), Marie Jakober's *The Black Chalice* (2000) and Suzette Elgin's *The Judas Rose* (1994). The effects of a theocracy are also explored outside of a feminist context, as in Lester Del Rey's *The Eleventh Commandment* (1962), John Brunner's *The Stone that Never Came Down* (1973), and Keith Robert's *Kiteworld* (1985).

With or without a theocracy, the priest or cleric is a fairly common protagonist. The strong religious grounding of such a character allows the author to examine human behavior in the light of challenges to one's religious or moral ground. Examples of clerical protagonists are found in James Blish's *A Case of Conscience* (1963), Marion Zimmer Bradley's *Darkover Landfall* (1972), Gordon Harris's *Apostle From Space* (1978), and Lester Del Ray's "For I am a Jealous God" (1973).

Science fiction is also an excellent vehicle for the consideration of moral questions. In *Science Fiction: The Future* (1971), Dick Allen describes the genre as "a form of literature that argues through its intuitive force that the individual can shape and change and influence and triumph; that [human beings] can eliminate both war and poverty; that miracles *are* possible; that love, if given a chance, can become the main driving force of human relationships" (p. 3). Ethical issues that are explored in science fiction include the appropriate use of technology, human relationships in the face of hardship, human responsibility in the face of new technologies, and the conflicts between disparate social groups or species. Many science fiction novels explore the conflicts that result when two societies with disparate ethical systems come in contact with one another. Examples include Isaac Asimov's *The Caves of Steel* (1954), Spider Robinson's *Night of Power* (1985), and Ken MacLeod's *The Cassini Division* (2000).

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NOREEN L. HERZFELD

SCIENCE, METHODOLOGICAL ISSUES

See PHILOSOPHY OF SCIENCE

SCIENCE, ORIGINS OF

An enquiry into the origins of science is immediately faced with fundamental questions about the nature of science itself. Is science a discrete activity that endures over time? Can it adequately be distinguished from related human activities such as magic and religion? Is it a peculiarly Western phenomenon? Traditional histories of science have tended to answer each of these questions in the affirmative. Science is customarily defined as the systematic description or explanation of natural phenomena along with the habits of mind that make that possible—typically logic and mathematics. Working with this understanding of science, historians have traced the origins of Western science to Greek thinkers living on the west coast of Asia Minor in the sixth century B.C.E.

Science in antiquity

The speculations of these ancient Greek philosophers—principally Thales (c. 625–546 B.C.E.), Anaximander (c. 611–547 B.C.E.), and Anaximenes (500s B.C.E.), all from Miletus—are regarded as distinctive for three reasons. First, they offered naturalistic accounts of various phenomena that differed significantly from earlier mythological explanations that invoked arbitrary or supernatural causes. Second, they attempted to deal with the universal rather than the accidental and particular, and they sought unitary, underlying principles that could account for the diverse phenomena of nature. Third, they engaged in rational criticism of alternative explanations. On the first count, while the Greek poets Homer and Hesiod had tended to attribute lightning or earthquakes to the anger of Zeus or Poseidon, the Milesian natural philosophers explained these phenomena in terms of the forces of nature. Thales, for example, believed that Earth was supported by water, and that earthquakes were caused by disturbances in the water in which the Earth floats. Anaximander suggested that thunder is caused by the wind. It should be noted that the Milesian philosophers were not, on this account, atheists—Thales had once observed that "all things are full of gods"—it was just that they excluded the gods from their explanations. These thinkers also endeavored to isolate a single material principle that could account for the varied forms found in nature. For Thales, this was water; for Anaximander, "the boundless"; for Anaximenes, air. Anaximenes also provided an explanation of the transformations that air would undergo in order to give rise to the diverse phenomena of nature. Finally, the Milesians engaged in the critical appraisal of rival theories, providing reasons why one hypothesis should be preferred to another. Again, this is quite distinctive, for the purveyors of myth found it unnecessary to defend their accounts in the face of alternatives, and seemed untroubled by inconsistencies between different mythological accounts.

These features of early Ionian science found their way into later schools of Greek thought. The sixth- and fifth-century Pythagoreans, for example, located the principles of all things in numbers, and demonstrated how numerical ratios were manifested in nature. They were the first to attempt to provide knowledge of nature with a mathematical foundation. The fifth-century atomists, by way of contrast, proposed that all physical objects were composed of different arrangements of atoms. These schools thus anticipated what were much later to become central features of modern science—the mathematization of nature and atomic theory.

Greek science culminated in the thought of Aristotle (384–322 B.C.E.), who was to provide such a comprehensive and compelling account of natural phenomena that it dominated much of Western thought up until the seventeenth century. Aristotle wrote on virtually every contemporary discipline—physics, logic, biology, psychology, along with metaphysics, poetry, ethics, and politics. His biological works were informed by impressively accurate observations of animals, and provide descriptions of their anatomy, reproduction, and behaviors. He also made enduring contributions to taxonomy. Most important of all, Aristotle developed a metaphysical framework that set out the conditions required for a complete explanation. These were Aristotle's four causes, which sought answers to fundamental questions of the "what," the "how," and the "why" of natural phenomena.

The scientific revolution

When Aristotle's writings were rediscovered in twelfth-century Europe, having been preserved in the interim by Islamic scholars, they became the cornerstone of the university curriculum, and were dislodged from this privileged position only after considerable controversy in the early modern period. Over the course of the seventeenth century the preeminence of Aristotle was successfully challenged by such figures as Galileo Galilei (1564–1642), Francis Bacon (1561–1626), René Descartes (1596–1650), Robert Boyle (1627–1691), and Isaac Newton (1642–1727). So great was the intellectual upheaval effected by these individuals that later historians were to describe their achievements as a "scientific revolution." This period witnessed the birth of experimental methods, the mathematization of nature, and the introduction of new taxonomic principles. It might thus be said that if science, broadly conceived, had its origins in the thought of the ancient Greeks, modern science, with its distinctive use of mathematics and experimentation, began in the seventeenth century.

Non-Western science?

This standard account of the origins of science is susceptible to a number of criticisms. These concern both Western claims to a monopoly on scientific thinking, and the idea that science has some identifiable essence or method that endures over time. One line of criticism points to archaeological evidence of remarkable technological achievements in China and the ancient civilizations of the near East, which preceded the speculations of the early Greek natural philosophers. However, it makes sense in this context to distinguish technology from science. The former could well be based on trial and error combined with accumulated experience. The practical ability to produce useful artifacts, however impressive, is something quite different from the systematic attempt to arrive at an understanding of the operations of nature as a whole or to provide a theoretical account of laws of nature.

It has also been suggested that the definition of *science* that operates in the standard account is too restrictive. *Science* might be defined more broadly as a set of behaviors geared towards mastery of the natural environment. On this more inclusive definition, *science* can be said to have originated in a number of different cultures at different times. There is a wealth of anthropological evidence that points to the fact that many traditional societies developed remarkably sophisticated and complex understanding of natural phenomena. Whether such indigenous knowledge counts as science will, of course, ultimately depend on how the term is defined. It must be said, however, and without wishing to devalue such traditional knowledge, that its inclusion in the category "science" tends to make that designation rather vague.

The nineteenth-century alliance

Perhaps the most telling criticism is the opposite contention, that the definition of science that informs the standard account of the origins of science is too broad. "Science," it can be objected, is a modern category, and not an ancient or even an early-modern one, and its application to those periods is anachronistic. The ancient Greeks did not have a word for *science* as we understand it, and thinkers from Thales to Aristotle regarded themselves as pursuing "philosophy." Something similar is true for other ancient cultures. A comparable situation also existed in the seventeenth century, when the disciplines "natural history" and "natural philosophy" were the closest analogues to modern science. Isaac Newton thus explicitly identified himself as being engaged in the pursuit of natural philosophy. Individuals like Newton did not think in terms of science and nonscience, and the now-familiar distinctions between chemistry and alchemy, astronomy and astrology, even science and religion, were at this time at best fluid, at worst meaningless. For much of the seventeenth and eighteenth centuries natural history and natural philosophy were intimately linked with religious concerns and included theological explanations. For this reason alone they are to be carefully distinguished from science as we understand it. The term *scientist* was not invented until the nineteenth century, and a good case can be made that it was only at this time that modern science came into being. During this period a new alliance of disciplines was formed, linked together by the professional designation "scientist." Natural history was superseded by a laboratory-based biology, and for the first time the sciences began to occupy a central place in the university curriculum. Crucially, just as the new professional category of scientist now excluded the clergy, who had hitherto played a central role in natural history and natural philosophy, the sciences eschewed religious explanations. Charles Darwin's (1809–1882) naturalistic account of the origins of life helped make this transition possible. The contemporary idea of science as a professional, secular activity that is conducted primarily in a laboratory setting dates from this period.

In sum, it is possible to answer the question of the origins of science in four ways:

(1) Science originated amongst Greek natural philosophers in the sixth century B.C.E.

(2) Science originates whenever and wherever human beings attempt mastery of their natural environment.

(3) The origins of science can be traced to the "scientific revolution" of the seventeenth century.

(4) Science began only with the professionalization of various scientific disciplines in the nineteenth century.

While there is something to be said for each of these alternatives, the last is perhaps the least anachronistic and most historically respectable.

See also ARISTOTLE

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PETER HARRISON

SCIENCE WARS

The term *science wars* refers to a complex of discussions about the way the sciences are related to or incarnated in culture, history, and practice. These discussions came to be called a "war" in the mid 1990s because of a strong polarization over questions of legitimacy and authority. One side of the controversies is concerned with defending the authority of science as rooted in objective evidence and rational procedures. The other side argues that it is legitimate and fruitful to study the sciences as institutions and social-technical networks whose development is influenced by linguistics, economics, politics, and other factors surrounding formally rational procedures and isolated established facts.

The science wars began when a group of scientists and philosophers of science launched fierce attacks on a cluster of schools of social, historical, philosophical, anthropological, and multidisciplinary science studies. Such programs are variously called *social studies of science*; *science, technology, and society studies* (often abbreviated STS); and *sociology of scientific knowledge studies* (SSK). The attack saw itself and presented itself as a counterattack necessitated by what the attackers felt was a growing destructive criticism of science and rationality. The assault was aimed not just at science studies but also at a general leftist/critical academic trend of disrespect of tradition, so that the science wars were, in effect, a front in the greater "culture war." In fact, several expressions of the attack have claimed to defend just such human and cultural values (e.g., socialism, feminism, critique of ideologies) that traditionally are the domain of the left, but were allegedly betrayed by the left's attempt to undermine traditional standards.

It may be argued that there need not be a conflict between the acknowledgement of the social and historical contextuality of science and its legitmacy and status as a resource for solving human problems. Indeed, much work in the philosophy of science after Thomas Kuhn's *Structure of Scientific Revolutions* (1962) has been devoted to the development of the affirmative understanding of scientific rationality and progress under the constraints of historicity and contextuality. But as schools of science studies began to develop more radical accounts, explicitly stating that no core of rationality is independent of history and context, with some of them making such statements as a direct provocative challenge to traditional understandings of science, the discussions turned into a bitter conflict, particularly in the United States, although a few fierce attacks have also been seen in Europe. The metaphor of a war tends to blur the great range of views within the schools of science studies, as well as the fact that the fierce counterattacks only represent a relatively small group of scientists.

The literature on science studies and their critical discussion is vast and only a fraction is mainly concerned with the issue of strong scientific realism versus radical social constructivism. The famous culmination of the science wars was physicist Alan Sokal's exposure of the lack of standards in his article "Transgressing the Boundaries: Toward a Transformative Hermeneutics of Quantum Gravity," published in 1996 in the leftist academic journal *Social Text.* A more complete expression of the science war argument was made by Paul Gross and Norman Levitt in the 1994 book *Higher Superstition.* Classical expressions of radical science studies are found in works by Barry Barnes and David Bloor, as well as Bruno Latour and Steve Woolgar. Less aggressive and more reflective discussions of the issues involved can be found in Andrew Pickering's 1992 book *Science as Practice and Culture.*

The science wars debate has obvious interest in the context of the science-religion relationship because it exposes the institutions of science and shows them reacting to a form of critical pressure with obvious parallels to the situation facing religion during the first centuries of modernity.

See also POSTMODERN SCIENCE

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NIELS VIGGO HANSEN

SCIENTIFIC MATERIALISM

See MATERIALISM; SCIENTISM

SCIENTIFIC METHOD

See MODELS; SCIENCE AND RELIGION, MODELS AND RELATIONS; SCIENCE AND RELIGION, METHODOLOGIES; SCIENCE AND RELIGION, RESEARCH IN; SCIENTISM

SCIENTIFIC REALISM

See CRITICAL REALISM

SCIENTISM

Advocates of the doctrine of scientism believe that the boundaries of science (that is, typically the natural sciences) could and should be expanded in such a way that something that has not previously been understood as science can now become a part of science. Thus a possible synonym to scientism is *scientific expansionism*. How exactly the boundaries of science should be expanded and what more precisely is to be included within science are issues on which there is disagreement.

Scientism in one version or another has probably been around as long as science has existed. From about 1970 to 2000, however, a number of distinguished natural scientists, including Francis Crick (b. 1916), Richard Dawkins (b. 1941), and Edward O. Wilson (b. 1929), have advocated scientism in one form or another. Some promoters of scientism are more ambitious in their extension of the boundaries of science than others. In its most ambitious form, scientism states that science has no boundaries: eventually science will answer all human problems. All the tasks human beings face will eventually be solved by science alone.

Epistemic and ontological scientism

The most common way of defining scientism is to say that it is the view that science reveals everything there is to know about reality. Scientism is an attempt to expand the boundaries of science in such a way that all genuine (in contrast to apparent) knowledge must either be scientific or at least be reducible to scientific knowledge. This epistemological form of scientism must be distinguished from its ontological form: The view that the only reality that exists is the one science has access to. One common way of stating ontological scientism is to maintain that nothing is real but material particles and their interaction. Ontological scientism entails epistemic scientism, but epistemic scientism does not entail ontological scientism. This is because one can affirm the view that knowledge obtainable by scientific method exhausts all knowledge and yet deny that whatever is not mentioned in the theories of science does not exist. One can do this because epistemic scientism does not preclude the existence of things that cannot be discovered by scientific investigation or experimentation. If there are such things, all it says is that one cannot obtain knowledge about them. Epistemic scientism sets the limits of human knowledge but not, like ontological scientism, the limits of reality.

It is often taken for granted that scientism and traditional religions such as Christianity and Islam are incompatible. But this is not necessarily the case. If, for instance, religion is taken to deal essentially with value questions, religion can be compatible with the epistemic and ontological forms of scientism. Of course, many believers are not satisfied with such a conception of religion. They claim that God really exists, that one can know that God is love, and so on. Are not such religious beliefs then incompatible with scientism? After all, scientism denies that it is possible to obtain knowledge of God or of a divine reality (epistemic scientism) and that there exists a transcendent or nonphysical reality beyond the physical universe (ontological scientism). But to the contrary, scientism does not necessarily deny these things. While Dawkins, Crick, Wilson, and others think along these lines, they could be wrong on scientific grounds. This is possible because all that scientism claims is that religious beliefs must satisfy the same conditions as scientific hypotheses to be knowable, rationally believable, or about something real. Scientists like Dawkins, Crick, and Wilson take for granted that religious beliefs cannot meet these requirements, which could of course be questioned. The British philosopher Richard Swinburne (b. 1934), among others, argues that theism can be confirmed by evidence in much the same way that evidence supports scientific hypotheses. Therefore, scientism cannot be equated with scientific naturalism or scientific materialism.

Value scientism and existential scientism

Another way of expanding the boundaries of science is to maintain that not only can science fully explain morality, but it can also replace traditional ethics and tell people how they morally ought to behave. Ethics can be reduced to or translated into science. However, for a claim to be *scientistic* in this sense, it must maintain more than that science is relevant to ethics. Nobody would deny that. It must rather state that science is the sole, or at least the most important, source for developing a moral theory and explaining moral behavior. There are advocates of this axiological form of scientism (called *value scientism*) within the ranks of evolutionary biology. Part of the idea is that evolutionary theory is rich enough to fully explain morality. The explanation is, roughly, that morality exists and continues to exist because it emerged and continues to function as a strategy adapted to secure the fitness of the individuals or of their genes. Some, like Wilson, even think that evolutionary biologists will be able to discover a genetically accurate and completely fair code of ethics and thus provide people with scientific, moral knowledge.

Defenders of scientism can also go beyond morality and expand the boundaries of science so that religion or existential questions fall within its scope. Existential scientism is the view that science alone can explain and replace traditional religion. Dawkins, for instance, maintains that since the advent of modern science, people no longer have to resort to superstition when faced with deep problems such as “Is there a meaning to life?” and “What are we for?” because science is capable of dealing with all these questions and constitutes in addition the only alternative to superstition. Wilson claims that science can explain religion as a whole material phenomenon and suggests that scientific naturalism or materialism should replace religion.

Some advocates of scientism endorse both value scientism and existential scientism. However, it is important to distinguish these two forms. It is possible to affirm that evolutionary theory is the sole, or at least the most important, source for developing a moral theory and explaining moral behavior, while at the same time to deny that biology or any other science can explain the meaning of human life or fulfill the role of religion in peoples’ lives. One could maintain that evolutionary theory can show which ethical principles should be used when trying to solve moral problems concerning (e.g., abortion, population growth, conflicts between people of different classes, genders, or races) and stop there, thereby accepting that the choice of religion or worldview is beyond the scope of science.

Thus value scientism does not entail existential scientism. But does existential scientism entails value scientism? This is less clear. Religions and worldviews generally include some ideas about how people should live and what a good life is. If this is correct then the acceptance of existential scientism implies also an acceptance of value scientism. But, on the other hand, it is perhaps possible to say that science alone can answer some existential questions and thus that science can partially replace religion. In other words, one doubts or denies that science can, so to speak, deliver the whole package in the shape of a complete worldview. If this is so, one could maintain, like

Dawkins, that every organism's sole reason for living is that of being a machine for propagating DNA, but still deny that science can offer ethical guidelines for how people should conduct their lives. Science can answer, at least, some existential questions, but it can not solve moral problems.

The relation between different forms of scientism

What then is the relation of value scientism and existential scientism to the first two forms of scientism? Neither value scientism nor existential scientism entails epistemic scientism or ontological scientism. It is coherent to claim that science can answer moral questions and replace traditional ethics or that science can answer existential questions and replace traditional religion, without maintaining that the only knowable reality or the only reality that exists is the one science has access to. Although there is no logically necessary connection between the two later forms, on the one hand, and the two earlier forms of scientism, on the other, these are, nevertheless, often combined.

This variety of forms of scientism shows that one should not equate scientism with scientific naturalism or materialism because there are possible forms of scientism that do not entail an acceptance of scientific materialism or naturalism. This variety also demonstrates that the relation between scientism and traditional religions is not a given. Only between existential scientism and traditional religions is there a direct conflict. Other forms of scientism may be compatible with traditional religions.

The main criticism directed against scientism is that its advocates, in their attempt to expand the boundaries of science, rely in their argument not merely on scientific but also on philosophical premises and that scientism therefore is not science proper.

See also MATERIALISM; NATURALISM; PHYSICALISM, REDUCTIVE AND NONREDUCTIVE; VALUE; WORLDVIEW

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MIKAEL STENMARK

SCOPES TRIAL

Perhaps the most famous symbol of the science-religion clash, the Scopes Trial took place during July 1925 in the small town of Dayton, Tennessee. On trial for teaching evolution was high school teacher John Thomas Scopes, who agreed to serve as defendant in a case to challenge Tennessee's recently-passed *Butler Act* (Public Acts of the State of Tennessee, 1925, Chapter 27). This statute was the first effective legislation that emerged from the anti-evolution crusade, the most dramatic manifestation of the religious movement known as Protestant Fundamentalism. The *Butler Act* prohibited the teaching in public schools of "any theory that denies the story of Divine Creation of man as taught in the Bible, and to teach instead that man has descended from a lower order of animals." The Scopes Trial was precipitated by citizens of Dayton, who hoped to use the resulting publicity to boost their community, and by the American Civil Liberties Union (ACLU), which hoped to secure a judicial ruling that such anti-evolution laws were unconstitutional. The trial attracted worldwide attention, in part because noted attorney Clarence Darrow (1857–1938) was a member of the defense team, while famous politician and anti-evolutionist William Jennings Bryan (1860–1925) assisted the prosecution.

The Scopes Trial generated significant media comment, virtually all of it negative. Writers such as H. L. Mencken portrayed Bryan and his supporters as buffoons and dismissed the rural South as a backward region. Although the trial produced a few dramatic moments, such as Darrow's examination of Bryan as a Biblical expert, the courtroom activity proved relatively inconsequential. The ACLU was unable to use the trial as a forum to discuss evolutionary concepts because the judge had prohibited expert testimony as irrelevant. Assuming that Scopes would be convicted, the defense planned an extensive appeal leading to the U. S. Supreme Court and thus took the Dayton proceedings somewhat casually. The local jury had little trouble finding Scopes guilty, after which the defense appealed to the Tennessee Supreme Court. Although this court affirmed that the *Butler Act* was legitimate, it overturned Scopes's conviction on a technicality and urged the state to drop the matter. This decision ended all appeals and left the constitutional status of the *Butler Act* undecided.

Although the Scopes Trial is often seen as a defeat for the anti-evolution forces, it actually served to stimulate the movement. Mississippi and Arkansas joined Tennessee in adopting anti-evolution statutes, all of which remained in place until the late 1960s. After the Scopes Trial, evolutionary concepts largely disappeared from the nation's public school science curriculum, as textbook publishers ignored the topic to maintain sales. During the final third of the twentieth century, new anti-evolution campaigns emerged in the form of "creation-science" and "intelligent design" arguments, which sought to convince the public that evolution was bad science and that there existed scientific evidence for the literal interpretation of the Genesis account of creation. Among the states that attempted to compromise the teaching of evolution in this fashion were Arkansas, Arizona, California, Indiana, Kansas, Louisiana, New Mexico, and Tennessee. Although efforts to enact state legislation to mandate the inclusion of these concepts in the science curriculum failed to survive constitutional analysis, the place of evolution in American public schools remained nebulous in the early years of the twenty-first century.

See also CREATION; CREATION SCIENCE; CREATIONISM; DARWIN, CHARLES; DESIGN; EVOLUTION; FUNDAMENTALISM; INTELLIGENT DESIGN

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GEORGE E. WEBB

SCRIPTURAL INTERPRETATION

The history of the relationship between scriptural interpretation and the rise of modern science is complex and convoluted. Within the so-called Abrahamic religions of Judaism, Christianity, and Islam, the relationship was intimately close from the Middle Ages to early modern era but became distant during the final decades of the twentieth century.

Key texts

When scholars in the Abrahamic traditions have addressed the relationship of science and religion, they have emphasized scriptural texts that assert God's role and activity as creator, sustainer, and governor of the universe. Key texts from the scriptures of Judaism and Christianity include the following:

- Genesis 1:1–28 31; 2:1–25; 5:1–2; 9:6
- Exodus 20:11
- 1 Samuel 2:8
- 2 Kings 19:15
- 1 Chronicles 16:26
- Nehemiah 9:6
- Job 9:8–9; 10:3, 8; 12:7–9; 26:7–13; 28:23–26; 37:16, 18; 38:4–38
- Psalms 8:3; 19:1, 4; 24:1–2; 33:6–9; 65:6; 74:16–17; 78:69; 89:11–12, 47; 90:2; 95:4–5; 96:5; 102:25; 103:22; 104:2–3, 5–6, 24, 30–31; 119:90–91; 121:2; 124:8; 136:5–9; 146:5–6; 148:5–6
- Proverbs 3:19; 8:26–29; 16:4; 22:2; 26:10; 30:4
- Ecclesiastes 3:11; 7:29; 11:5

- Isaiah 17:7; 37:16; 40:12, 26, 28; 42:5; 44:24; 45:7, 12, 18; 48:13; 51:13, 16; 66:2
- Jeremiah 5:22; 10:12–13, 16; 27:5; 31:35; 32:17; 33:2; 51:15–16, 19
- Amos 4:13; 5:8; 9:6
- Jonah 1:9
- Zechariah 12:1
- Mark 10:6; 13:19
- Acts 4:24; 7:50; 14:15; 17:24–26
- Romans 1:20; 11:36
- 1 Corinthians 8:6; 11:12
- 2 Corinthians 4:6; 5:5, 18
- Ephesians 3:9
- 1 Timothy 6:13
- Hebrews 1:1–2; 2:10; 3:4; 11:3
- Revelation 4:11; 10:6; 14:7

Key Islamic texts from the Qur'an include the following: 2:23–30, 3:190, 4:1, 6:38, 6:98, 7:189, 10:90–92, 11:7–13, 15:26, 15:28, 15:33, 16:66, 17:88, 21:30, 22:61, 25:59, 36:36, 39:6, 41:53, 42:47, 43:12, 50:38, 51:47, 54:49, 55:33, 57:6, 71:14, 76:1, 79:30, 91:7–8, 96:2.

These texts are referenced with great frequency in scriptural commentaries of the Abrahamic religions. They are characterized by their description of a single deity, who creates and maintains the universe and guides human beings in their relations with this deity and their world.

Premodern period

In many respects, the first-century Jewish theologian Philo was the first to draw a connection between the natural philosophy of the ancient world and scripture. In his *On the Creation,* Philo reflects upon God as creator of the universe, draws comparisons with Greek philosophy, and offers correctives based upon scripture. The great early Christian scriptural scholar and theologian Origen (182–251) builds on Philo in his commentary on Genesis and the first of his Christian theologies, *On First Principles*. In these works, Origen establishes the basic tendency of Christian theology to appropriate natural philosophy while following scripture. Early in the history of Christian theology, scripture is not regarded as in conflict with scientific knowledge of the world, although some early interpreters of scripture sought to correct ancient science by rejecting the notion of the eternity of the universe.

The millennium that spanned the fourth to the fourteenth centuries brought forth an abundance of Jewish, Christian, and Muslim reflection on scripture and science. Jewish scriptural interpretation during the early part of this period was largely devoted to the refinement of its religious traditions in an effort to sustain Jewish diaspora communities. Scientific reflection was not entirely absent in Jewish theology of the period, but it does not become extensive until the appearance of Maimonides (1135–1204). In Maimonides's writings, scripture is regarded as not at odds with knowledge of the natural world, although Maimonides did believe that scripture could provide a corrective to that knowledge at crucial points. He asserts that the universe was created *ex nihilo* (from nothing); that is, the story of God's creation excludes the possibility that the universe was made of eternal or pre-existing matter. Indeed, divine action includes a relation to every individual entity rather than either detachment or panentheism. Maimonides is also remarkable for his early rejection of astrology in favor of an "astronomical" approach to the study of the universe.

The Christian theologians Athanasius (c. 290–373) in the East and Augustine (354–430) in the West offered arguments from scripture that God was the creator of all things and that therefore the universe could not be identified with God because it had a beginning. Maximus Confessor (580–662) further asserted that scripture teaches the freedom of God in creation, a view that countered the ancient metaphysical notion of the inferiority of physical matter. Instead, the dictum that God created everything by free initiative and with good intentions suggested a moral harmony between matter and spirit. The *Summa Theologica* of Thomas Aquinas (1225/26–1274) represents the pinnacle of medieval Christian reflection on the relation between scripture and science. Aquinas's major contribution to the discussion was his argument for the design of the universe. Indeed, it is his reading of God as the designer of all things, as opposed to the classical universe of eternal forms and temporal objects, that formed the basis of Aquinas's five "proofs" for God's existence.

Islam reached the height of its scientific attainments during the medieval period when enormous resources were brought to bear in support of Islamic science. During this time, the scripture was not considered incompatible with knowledge of nature, and astronomical science was considered necessary because every Muslim throughout the world was required by the Qur'an to turn toward Mecca to pray. The early development of astronomical science was necessary in order to plot a point on any horizon toward which the devoted would bow. As a result, Arabic mathematics and astronomy flourished with the likes of Abu Isa al-Mahani (c. 860–874/84); Hamid ibn Ali, the inventor of the astrolabe; and Jabir ibn Sinan al-Battani (c. 858–929). These men, probably the greatest of the Muslim astronomers, developed numerous standard astronomical formulas.

Islamic science is characterized by close attention to the Qur'an and its stress upon the correspondence between the one deity, Allah, and the uniform lawfulness of the universe. The Muslim anatomist and philosopher Averroës (also known as Ibn Rushd, 1126–1198) expressed a typical opinion when he said that the study of the natural world strengthened belief in the Qur'an. Averroës's rejection of absolute determinism and absolute free will is largely the result of his avoidance of any particular philosophical conclusion and his reliance on the religious narratives of the Qur'an. Western scholars depended on Arabic copies of ancient texts, and Averroës's commentaries on Aristotle, which interpret Aristotle according to a monotheistic scripture, greatly influenced Thomas Aquinas. Muslim science continued to advance until the fourteenth century, after which it suffered setbacks that persist into the twenty-first century. Many interpreters of culture regard this reality as rooted in the struggle of religion to come to grips with the successes of modern science.

Modern period

Christianity, Judaism, and Islam experienced different fates from the sixteenth to the final decades of the twentieth century. As the natural sciences began to receive widespread patronage from the noble and mercantile classes in the West, religious and political realities prohibited Jewish and Muslim involvement.

One of the events that marks the beginning of the modern period in science is the astronomical labors of Nicolaus Copernicus (1473–1543). His great work, *On the Revolutions of the Celestial Spheres,* published shortly before his death, established the heliocentric model of the solar system. This system was defended by Johannes Kepler (1571–1630) and Galileo Galilei (1564–1642), but was condemned by the Vatican. Galileo's motto concerning scripture has become something of a byword for how persons of faith reconcile their study of the natural world with their readings of scripture: "The intention of the Holy Spirit is to teach us how one goes to heaven, not how heaven goes." In attempting to substantiate the Copernican rejection of an Earth at rest in its celestial position, Galileo cited Proverbs 8:26, which speaks of the "hinges" of the Earth, and therefore its motion. Kepler's view regarding scripture was different and represented an early strategy of coping with the moments in interpretation when science and scripture appear to be at odds. This strategy was to define scripture as governing religious experience and moral development; as such, it was proposed that religion should simply rule its own domain and avoid the domain of science.

The Reformation of the sixteenth century, spawned by the religious writings of Martin Luther (1483–1546), Huldreich Zwingli (1484–1531), John Calvin (1509–1564), and others, established an important epistemological principle that aided the advancement of scientific method, namely the investigation of sources over against traditional authorities and practices. To the extent that scripture was regarded as the source of true religion, the Reformation encouraged a kind of experimental attitude in which it was assumed that traditions and schools of interpretation could be subjected to critical methods in the interest of advancing truth. Experimental science, which had to contend with traditional assumptions about the world within the wider culture, won a measure of courage from the developments within religion itself. Protestantism tended to be much more open to scientific advancement; in many ways it adapted to what it regarded as the necessary implications of such advancement. Examples of this would include the compatibility of the scriptural notions of creation, prophecy, miracles, and religious experience with various scientific understandings of the universe and of human nature.

In many respects, the role of scripture as primarily the source of religious experience and moral formation emerges as an ongoing resource for science, since scientists themselves are cultural beings. Indeed, this view was one of the characteristics of the transition to postmodernism in science and religion. The English philosopher of science Francis Bacon (1561–1626) in his great work *Novum Organum: Indications Respecting the Interpretation of Nature* (1620) was enamored with an analogy of two sources or "books" of human knowledge: scripture and nature. Both, according to Bacon, came from God, but they had separate, albeit related, functions in human life. Bacon believed that it was necessary for a scientist to follow Jesus' teaching to "become like a little child" before the natural world in order to be freed from the arrogant prejudices that blocked experimental thinking. A kind of humility, a first admission of ignorance, was required before observation and the recording of empirical data could serve as an authority for scientific inquiry. For Bacon, even earlier successes in science must not hold captive any future practice of science. Much of what allowed this development was the Protestant capacity for self-critique and an allowance for the separation of the domain of science from that of religion and scripture.

But these early modern attempts at reconciling science and scriptural interpretation did not produce all of the cultural changes needed for the advancement of science. Extreme skepticism was engendered by a penchant on the side of religion for "scientific proofs" for divine existence and presence in the world. From Gottfried Wilhelm Leibniz (1646–1716) to William Paley (1743–1805), numerous arguments to "prove" the existence of God were advanced on commonly accepted philosophical grounds. Unfortunately, these arguments are fraught with problems because scriptural traditions do not claim that the natural knowledge of God's existence can be cognitively derived from such "proofs." The upshot was a bifurcation of faith and science, with the latter assuming a kind of ideological status sometimes called *scientism*. Scientism during the nineteenth century tended to be positivistic and to rule out the possibility of sensible claims for the knowledge of God and, therefore, any truthfulness to religious scriptures. Fortunately, during this century, restrictions in the West toward the presence of Jews in the universities began to disappear and Jewish science achieved a great revival. Islamic scientists also made their way into major research centers during the latter part of the century.

Late modern era

The modern distancing between religion and science has meant for some a kind of fundamentalist abandonment of science for a supposedly scripture-based view of the world. So-called creationists claim that certain literal interpretations of scripture are the only permissible ones. For others, however, the preferred approach is the recognition of the respective domains of religion's interpretation of scripture and science's interpretation of nature. Since the time of Charles Darwin (1809–1882), natural science has been understood by many interpreters as compatible with the narratives of their religion's scriptures. Such approaches transcend the politically charged labels of "liberal" and "conservative" and more often reflect the kind of cultural space where scriptural interpretation is accomplished. Science does not require scripture, let alone metaphysics, to perform its work, but its work is often performed by persons religiously committed to classic religious texts and metaphysical systems. Throughout the twentieth century, proponents of scientism have had to acknowledge the limits of science and, with this acknowledgement, the persistence of religious interpretation of scripture as a guide to the lives of many scientists and a scientifically shaped world.

In many respects, the transition from modern to late modern is marked by the use of criticism as an intellectual enterprise. The modern tendency of maintaining a "critical distance" between science and religion (and its scriptures) is paralleled by the late modern tendency to maintain a "critical distance" between culture and science, whereby science is not considered to be the sole source of knowledge of the world. Although this situation could be regarded as a fragmenting of culture, it also represents attempts to resolve what the philosopher Immanuel Kant (1724–1804) called "the conflict of the faculties." The many disciplines of human inquiry possess a mutual compatibility because they are all part of the cultural project of understanding the world. Each make their own contribution and, not surprisingly, scriptural interpretation as a religious practice continues to contribute to that project.

See also AUGUSTINE; AVERROËS; CHRISTIANITY; CREATIONISM; DARWIN, CHARLES; FUNDAMENTALISM; ISLAM; JUDAISM; SCIENTISM; THOMAS AQUINAS

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SECOND LAW OF THERMODYNAMICS

See ENTROPY; THERMODYNAMICS, SECOND LAW OF

SELECTION, LEVELS OF

In the *Origin of Species* (1859), Charles Darwin introduced his theory of *natural selection,* the generally accepted mechanism for evolutionary change. More organisms are born than can survive and reproduce; there will consequently be a struggle for existence. Given naturally occurring variation, the struggle will bring on a process equivalent to a breeder's artificial selection: a *differential reproduction* leading to evolutionary change of a kind that centers on adaptation, producing contrivances like the hand and the eye. A matter of immediate interest was the level at which natural selection was supposed to operate. Does the struggle occur between individuals or between groups like species? If the latter, can adaptations benefit the group at the expense of the individual? Could one have "altruistic" adaptations where, instead of an organism selfishly serving its own ends, it sacrifices its well-being and possibilities for reproduction to the common good? Darwin himself was inclined to think not, although he did equivocate with regard to human beings. A contrary tradition was initiated by the co-discoverer of natural selection, Alfred Russel Wallace, who, as a good socialist, was convinced that selection can work for the good of the group, even if the individual suffers thereby.

Matters went essentially unresolved until the 1960s. Although some (notably R. A. Fisher) stuck to the Darwinian line, a position like Wallace's, endorsing what came to be known as *group selection,* was assumed implicitly by most evolutionists. Then a strong reaction set in, and thinking swung to a Darwinian mode. Biologists realized that the trouble with group-directed altruistic adaptations is that they are open to cheating. While the altruist is working for the good of the group at its own expense, the selfish individual is benefiting thereby, and at the same time serving itself by refusing to direct any effort to others. Selfishness will therefore win out in the struggle for existence and altruism will go extinct.

At about the same time, a number of new models based on selection for self (*individual selection*) were devised. Notable was the idea of *kin selection,* introduced by British evolutionist William Hamilton, which showed how close relatives help each other for shared biological ends.

Particularly impressive was the way in which Hamilton demonstrated how his new mechanism could account for the sterility of worker ants, bees, and wasps. These groups are exceptional in that only females have both mothers and fathers, males being born of unfertilized eggs. This leads to nonstandard genetic relationships where females are more closely related to sisters than they are to daughters. Hence, selection favors adaptations (including sterility) that motivate females to raise fertile sisters rather than fertile daughters. In so doing, one is accomplishing more to increase one's genetic representation in future generations than one would if one followed more traditional patterns of reproduction.

The Hamiltonian-type approach is often referred to as *genic selection* because ultimately it sees evolution as a matter of the sorting of the genes, the units of inheritance, and evolutionary change as a simple function of change of gene ratios. While this is true, it does not mean that the individual organism drops out of sight, for it is organisms that package genes and it is organisms that compete in the struggle for existence. For this reason, it is helpful to distinguish between genes as *replicators,* the markers of evolutionary change, and organisms as *vehicles* or *interactors,* the carriers of genes and the units that struggle for supremacy. At both levels and in both appropriate senses, one has units of evolution.

Other models similar to kin selection were devised showing how "selfish genes" can nevertheless lead to cooperative behavior between organisms. The best known is perhaps *reciprocal altruism* (something of which Darwin had an inkling) where organisms cooperate because benefits given are linked to the expectation of benefits to be received. At the same time, students of the evolution of social behavior turned to game theory to work out how organisms, mainly animals but some plants, adopt different strategies to maximize their evolutionary success. This activity is all a thriving part of the evolutionary enterprise, both theoretically and empirically. It is true that in the past a number of evolutionists have produced theories and experiments showing that, under certain circumstances, group effects within a species can swamp individual interests, but this is in no sense a return to old-fashioned group selection. It is also true that some paleontologists think that in the course of history one sees some species succeeding in systematic ways, while others do not. But such *species selection* is compatible with an individualist approach at the level of the organism. There is a richness to the evolutionary process, something that can work in many ways and at many levels.

See also ADAPTATION; ALTRUISM; EVOLUTION; FITNESS; SELFISH GENE

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MICHAEL RUSE

SELF

Although it has been a subject of fascination for thousands of years, *self* is an ill-defined concept in philosophy and psychology, generally taken to refer vaguely to the "inner" being of the individual that is, at times, both the subject and object of experience. It should be seen as distinct from both *person* (the totality of an individual being) and *identity* (an individual's sense of who they are in relation to a social and physical world). When people refer to the "problem" of the self, they are, in fact, referring to a great many problems. Is there really a self at all? What sort of methodology should be used to investigate it? Does a person have one self or many selves? Where is the self located? How does the self develop? How does one self interact with another? What is broadly agreed is that the experience of self is somewhat paradoxical since the self can appear to be simultaneously unified yet fragmented, continuous yet disparate, immanent yet transcendent, apparent yet elusive, private and personal yet social. These problems, as they arise in the behavioral sciences, share a history with the world's religions. Theologians and philosophers alike have attempted to address them.

The self in psychology

In the 1890's psychologist and philosopher William James (1842–1910) proposed that the self-as-subject, the *I-self,* be differentiated from the self-as-object, the *me-self.* His model contended that the me-self, which is created from an individual's subjective interpretation of experience, could be subdivided into three components: the bodily, material self at the bottom; the social self in the middle; and the spiritual self, the extremely precious enduring dispositions and moral constitution of a person, at the top. The elusive I-self, he proposed, is an active agent that is able to shape its own destiny and is responsible for perceived continuity and the construction of the me-self.

James's differentiation of "me" and "I" remains intrinsically attractive to many theorists, but although an abundance of complex structural and systemic models of the self have been proposed, the very existence of the I-self is still frequently questioned. Empirical and theoretical psychology, however, has generally taken each individual's development of a sense of an inner self for granted.

One way of categorising models of the self is through their division into *global unidimensional models,* which emphasize a single factor such as the importance of self-esteem for the maintenance of the self, and *multidimensional models,* which implicate a network of hierarchically organized cognitive structures that collectively constitute the self. Though these two types are not strictly antithetical, there has been a dramatic shift towards hierarchical models in recent years and the self is more often discussed as a complex system rather than a unitary entity.

On these lines, the psychologist George Kelly argued that the self-system should be likened to a theory constructed by the individual, which serves to organize their relationship to the world. Some information processing models suppose that the individual's cognitive experiential organization results in the formation of *self-schemata,* which are constructs that serve both to give a sense of self and to guide and govern future behavior. Others argue that the components of what is generally known as the self are interconnected so as to form a loosely integrated whole giving the illusion of continuity but continuing to exist as a multiplicity, each retaining the capacity for a degree of autonomous functioning—in the cognitive scientist Marvin Minsky's terms, a "society of mind." A common way of accounting for the apparent sense of an inner self, whilst remaining ambivalent about its literal existence, is to appeal to the idea of narratisation—the notion that what is called a self is actually just a dynamic process of integrating a personal experiential history into a coherent unified life story. The autobiographical narrative so constructed effectively amounts to a person's unique identity, but this does not equate to some mysterious transcendent inner entity. Many have argued, however, that the demands of living in postmodern society raise certain difficulties for an individual's construction of a singular coherent identity; the essential fragmentation of the self is a common theme in postmodern thought.

Social psychology is concerned not so much with the individual representation and functioning of the self but with its genesis and development in a social context. In William James's opinion, there was not one single "social self" but, rather, a multiplicity, each of which could find expression at any one time. This idea of multiple selves that are essentially relational, situation-specific constructs arising from social encounters, is a central feature of social psychological models. In 1902 sociologist Charles Horton Cooley (1864–1929) and, subsequently in the 1920s, philosopher and social psychologist George Herbert Mead (1863–1931), developed perspectives in which an individual's social interactions in the form of linguistic exchanges (symbolic interactions) were deemed to be central to the construction of self. Indeed the theory of the social construction of the self finds its most straightforward expression in Cooley's famous concept of the "looking-glass self," the idea that an individual comes to know themselves only by assimilating the reactions of others towards oneself into a self-image. Here, the "me" and "I" components of the self are deemed to be interdependent, each continuously redefining the other. Modern empirical social psychology has identified a variety of different socially determined factors that come to bear on the development of the self, even to the extent that an individual's perceptions of especially close others may come to be integrated into their concept of themselves.

Other, psychoanalytic theories, most notably object relations theory, also emphasize the importance of the role played by an individual's relationships in the healthy development as well as the psychopathology of the self. According to object relations theorists, who rejected the Freudian psychosexual developmental model of the individual as narcissistic and pleasure seeking, the self develops as a complex matrix of representations acquired through emotionally laden experiences of oneself in relation to others.

So, different theories have collectively enhanced the knowledge of the self, but none could individually lay claim to offer a complete account. Psychoanalytic psychology, for example, has the benefit of a holistic approach to the self and the personality, but not the (alleged) fine grained, empirically verifiable explanatory power of information processing approaches. Information processing accounts, by contrast, often fail to pay adequate heed to the roles of affective psychological processes when modelling the self. Despite considerable differences of opinion over its contributory structures and processes, competing theories of the self do generally converge on a number of basic principles, such as its essential dynamism and the notion that much of the self remains unconscious, invisible to introspection. Some recent work has been directed towards further uniting apparently disparate theories of the self that have arisen in distinct psychological schools.

Non-western concepts of the self are often difficult to translate into western psychological terminology. Although the sense of self has frequently been supposed to be an innate, pan-cultural feature of the human psyche, ethnographers are agreed that what amounts to the sense of self arises from a vast array of interconnected individual-cognitive and sociocultural influences. The innateness controversy rages on, but it appears unlikely that anything as complex as the self could be determined by the genes of an individual. All this is not to say, however, that evolutionary theories of the phylogeny of the self should be discounted; the "modern" self, in as much as it is partly determined by evolved mental and physiological processes, must surely have been influenced by the pressures of natural selection.

The self in religion

Several theorists have observed that Christian theological notions of the soul are the immediate ancestors of Western philosophical and psychological notions of the self, and there is a very strong tradition of positioning knowledge of self in conversation with Christian doctrine and the knowledge of God. Contemporary analyses of this tradition such as Charles Taylor's *The Sources of the Self* (1989), which charts the genesis and phylogeny of the modern identity in Western philosophy and social thought, traces the origin of introspection back to Augustine of Hippo (354–430 C.E.), although the writings of mathematician and philosopher René Descartes (1596–1650) effectively inaugurated the form of critical self-reflection that characterises the "modern" period. Often, the theological influence on the development of thinking about self in non-Christian cultures is also readily apparent. Personal senses of self, as well as concepts of the nature and function of the self in a religious context, differ markedly between cultures. These range from those of the modern western Christian world, with their overt emphasis on individualism and personal autonomy, to those of certain cultures and other religious traditions where concepts of person and self are less explicit or even absent.

In the western world, then, the origin of the "inner self" as an inwardly focused and centered entity that is distinct from the physical body lies in the works of Augustine, who emphasized the importance of adopting a first person standpoint in the understanding of oneself, and in doing so, fundamentally changed the way that people conceived of the soul and subsequently the self. For Augustine, appreciation of the meaningful order of the world, grounded in the goodness of God, was possible only through introspection of the soul. God, as an inner light—the light of the soul—was conceived by Augustine to be the underlying principle of knowing itself.

A major strand of Christian theological thought concerning the origin and nature of the inner self can be identified in discussions that are centred upon the *imago dei,* the triune God in whose image, Christianity teaches, human beings are created. Augustine's discernment of the triadic structures of human thought, which he grounds in the being of God is a celebrated example of this type of theory, but this theme has been revived and elaborated upon many times.

Conceiving the nature of God as Trinity, some (such as Alisdair McFadyen) argue that a theory of human nature might be analogously informed. They argue that the model of the Trinity as a unique community of persons does not entail the autonomous individuality of each person nor an understanding of each person as a specific mode of relation to the other persons of the Trinity. Echoing of the *dialogical personalism* developed by the Jewish thinker Martin Buber, this understanding of the Trinity is reflected in the understanding of human persons as acquiring identity only through their relations with others, including their relationships with God. At all times an individual self is engaged in a threefold living relation with human others, with his or her environment and, through faith, with God.

In Islam, where the word *Nafs* may be equally well translated as soul or self, it is generally discussed in the context of *Hudan* (the right guidance), and the appropriate path to virtue as taught in the Qur'an. Although the Islamic concept of the soul is affected by both inner and cultural factors the notion of an essential self is less explicit than in the West, being more of a social construct made manifest through the taking of roles. In submission to Allah the self is both controlled and cultivated as part of a hierarchical cultural and religious order.

The various collections of teachings subsumed under the generic name Buddhism, by contrast, teach that the sense of an inner self (which is really not-self), as expressed in words such as "I" and "me," is a source of suffering and that only through surrendering this sense can a state of bliss really be found. All sentient beings are deemed by Buddhists to be part of a continuous cycle of birth, death, and rebirth. Nirvana, effectively the escape from this cycle, can only be achieved by a successive rooting out of all greed, hatred, confusion, and delusion from what passes as one's self. In Buddhist thought, it is by ceasing to grasp after the perceived continuity of self, and thereby accepting the present as an opportunity to develop the cardinal virtues of wisdom and mindfulness that one might finally and completely transcend the process of becoming.

The self at the interface of psychology and religion

Some psychologists and philosophers of religion have succeeded in coordinating certain aspects of their respective theories and models of the self and in many cases these theories are mutually informative. Francisco Varela, in *The Embodied Mind* (1991), for example, draws his primary inspiration for his theory of the self from *Mahayana* Buddhist teachings. However, although empirical social and cognitive psychology has attempted to quantify the impact of various religious influences on self-development, the emphasis on explanation in these models seems very different to the more interpretative, discursive theories that have arisen in theological discourse. Although not all psychological theories of the self are as antitheological as those of Sigmund Freud or some evolutionary psychologists, even those psychological models of mental health and development that accentuate the importance of an individual's perceived relationship to God portray the self in a fundamentally different light to that of explicitly religious theories. It tends to be seen as a product of innate and acquired individual and social influences rather than, as in Christian thought for example, an entity created and sustained by God, which stands in perpetual relation to God. It seems, then, that although the relationship between religious and psychological theories of the self has great historical significance, and there may be dialogue between them, their objectives, their identities and, ultimately, their raisons d'être remain distinct.

See also BUDDHISM; DESCARTES, RENÉ; EVOLUTIONARY PSYCHOLOGY; EXPERIENCE, RELIGIOUS: COGNITIVE AND NEUROPHYSIOLOGICAL ASPECTS; FREUD, SIGMUND; GOD; IMAGO DEI; ISLAM; PSYCHOLOGY; SELF-TRANSCENDENCE; SOUL

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FRASER WATTS

SELFISH GENE

The term *selfish gene* was coined by Richard Dawkins (b. 1941) in his 1976 book of that name to convey the central sociobiological idea that it is reproductive success, rather than individual excellence, that determines the course of evolution. Thus "the survival of the fittest" does not really mean the survival of outstanding individuals themselves. It means the prevalence of their type in later generations through increasing numbers of descendants.

Biologists such as J. B. S. Haldane (1892–1964) had suggested this understanding of evolution as a solution to the "problem of altruism"—that is, the question how it was possible for animals often to act in ways that sacrificed their own individual interests to those of others around them. This undoubtedly happens, not only in the care of the young but in many other social activities. How had the trait developed? The answer lay in reproduction. Tendencies to act altruistically can survive and spread through a species, even if they shorten the life of their first owners, provided that those owners have first transmitted them to a sufficient number of descendants. Thus it is the genetically-determined trait rather than the individual that, in some sense, is selected and survives.

Dawkins's contribution to this approach was to dramatize it by depicting the gene involved as a kind of counter-individual—a hidden agent exploiting the organism it rides in:

> We are survival machines—robot vehicles blindly programmed to preserve the selfish molecules known as genes. . . . We are machines created by our genes. Like successful Chicago gangsters, our genes have survived, in some cases for millions of years, in a highly competitive world. This entitles us to expect certain qualities in our genes. I shall argue that a predominant quality to be expected in a gene is ruthless selfishness. . . . A gene leaps from body to body down the generations, manipulating body after body in its own way and for its own ends, abandoning a succession of bodies before they sink in senility and death. The genes are the immortals. (pp. x, 2, and 36)

This powerful image certainly conveyed the point about the importance of reproduction. But the cost in clarity has been heavy.

The dramatic picture of genes as freeloading individualists is not actually compatible with serious genetics. Genes are not fixed units at all. They are varying lengths of DNA, and they cannot take effect without cooperating in highly complex groupings. Nor, of course, are they immortal, since each gene dies with the cell that it belongs to. It is only their type that survives—just as a species survives the death of its individual members. This may not be a very interesting kind of immortality

However, the most substantial scientific question that does arise here concerns the level at which natural selection takes place. Sociobiologists resisted earlier suggestions that new developments were directly determined by the interest of the group or of the species. They rightly pointed out that, in order for inherited traits to change, there must be changes at the genetic level. Gene-selection must therefore indeed operate.

It is not, however, obvious that gene-selection excludes selection at other levels also. At the individual level, organisms are not powerless vehicles. An individual animal can influence the evolution of its species by, for example, exploring a new habitat or finding a new source of food. At the level of selection between groups, social tendencies can have considerable effect on species-survival, though in less direct ways than earlier theorists had supposed.

These scientific issues are still being discussed, although they may not have much direct relevance to the relation between science and religion. What does make the topic relevant here is Dawkins's rhetoric: His personification of genes as forces ruling helpless humans seems to involve a sort of fatalism, and his choice of the word *selfish,* instead of some neutral term such as *selectable,* to describe the part that genes play in evolution gives this fatalism a personal twist by appearing to credit these forces with a motive. This is recognizable religious imagery.

What is the point of the colorful metaphor? Readers often see in it the familiar doctrine of psychological egoism—the view that selfishness, in the literal, everyday sense of self-interest, is the sole motive determining the behavior of all organisms, including humans. This, however, cannot be right, and it is not what Dawkins is technically saying. He, like other sociobiologists, is trying to solve the problem of altruism—that is, to explain why animals often act against their own interest. Dawkins's explanation is that they are pawns, being manipulated in the interests of the genes. Yet he often writes as if he did attribute the selfishness to the organisms themselves:

> Be warned that if you wish, as I do, to build a society in which individuals cooperate generously and unselfishly towards a common good, you can expect little help from biological nature. Let us try to teach generosity and altruism, because we are born selfish. Let us understand what our own selfish genes are up to, because we may then at least have the chance to upset their designs, something which no other species has ever aspired to. (p.3)

In this and similar passages there is a radical confusion between attributing selfishness to genes in a technical sense, as a causal property in population genetics, and using the word with its normal meaning to describe a motive attributed to individual organisms. Other sociobiologists such as Edward O. Wilson (b. 1929) also constantly slide into this ambiguity between the technical and the everyday sense of the word, though most of them use it only for organisms, not, like Dawkins, for genes.

The confusion is perhaps a natural consequence of choosing to use such a highly emotive everyday word as *selfishness* as a technical term. In any case, it seems plain that the official, scientific message of sociobiology does not actually give any kind of support to psychological egoism. As for Dawkins's alarming suggestions of fatalism, the last sentence of the passage just quoted implies that they are meant rather as melodrama than as serious determinist metaphysics.

See also ALTRUISM; DNA; EVOLUTION, BIOLOGICAL; GENETICS; NATURAL SELECTION; NATURE VERSUS NURTURE; SOCIOBIOLOGY

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MARY MIDGLEY

SELF-ORGANIZATION

The term *self-organization* refers to a spontaneous emergence of order in complex processes. The idea of an emergence of order has very old roots, but its importance as a scientific concept, and concomitantly its relevance for the ongoing science and religion debate, have only recently been recognized.

History of the idea

Though the idea of self-organization is often presented as a twentieth-century revolution in science, some of its basic notions are as old as human reflection on the origin of the world's orderliness. Many cosmogonic myths narrate the struggle between chaos and cosmos, and the emergence of order out of chaos.

In ancient philosophy, Heraclitus (c. 540–480 B.C.E.), Aristotle (384–322 B.C.E.), and Lucretius (c. 96–55 B.C.E.) attempt to rationally cope with nature's self-organization. In modern times, germs of the contemporary theory of self-organization are to be found in René Descartes (1596–1650), Gottfried Wilhelm Leibniz (1646–1716), and Immanuel Kant (1724–1804), who in his *Kritik der Urteilskraft* (*Critique of Judgment,* 1787) introduced the term *self-organization*. After Kant the idea of self-organization was a focal point in the philosophy of nature of Friedrich Schelling (1775–1854) and in the metaphysics of Alfred North Whitehead (1861–1947).

In scientific discourse, the concept of self-organization was introduced in 1947 by W. Ross Ashby, who elaborated on it in the context of cybernetics and systems theory. From the 1950s on, the scientific idea of self-organization was further developed by Heinz von Foerster (order from noise); Ilya Prigogine (dissipative structures); Hermann Haken (synergetics); Humberto Maturana and Francisco Varela (autopoiesis); Manfred Eigen (hypercycles); Norman Packard, Chris Langton, and Stuart Kauffman (the edge of chaos); Per Bak (self-organized criticality); and many others.

The scientific concept

Self-organization is the process of the spontaneous emergence and maintenance of order in a complex dynamic system. The capacity for self-organization enables the system to develop or change its internal structure spontaneously and adaptively in relation to its environment. The term *spontaneous* is meant to refer to the absence of control by an external or central agent. The global ordering results from interactions between the initially independent components of the system, all of which follow their own local laws. Thus, the development of the ordered structure takes place primarily in and through the system itself.

One of the fundamental traits that distinguish self-organizing systems from systems studied in more traditional cybernetics is the absence of centralized control. The "control" of the organization is typically distributed over the entire system. Because of this distributed character, such organization tends to be robust and to resist perturbations.

The internal and distributed "control" is often effected by circular or network relations between the components. Though the laws governing the global behavior are still imperfectly understood, the complex process is known to generally involve positive feedback loops alongside the "normal" negative feedback loops (known from standard cybernetic control systems). Negative feedback works to stabilize by reducing variations; positive feedback on the other hand amplifies the variations (e.g., autocatalytic processes). The interaction between these two forms of feedback may create a nonlinear dynamics, intricately developing itself until it reaches a stable situation, an *attractor*.

An attractor is a state, or set of states, toward which the system tends to evolve, and in which, when reached, it tends to stay. If the attractor contains an infinite number of states so that the system oscillates in an a-periodic way between them, the system is said to be chaotic An isolated system usually has a single, trivial, attractor: the equilibrium state with maximum entropy ("disorder"). A self-organizing system, conversely, evolves toward an ordered state. This may be an ordered equilibrium state (e.g., in crystallization), but in typical complex self-organizing systems (such as living organisms), it will be an ordered nonequilibrium (in those systems equilibrium means "death"). Such ordering processes may seem to contradict the entropy law of thermodynamics. This, however, is not the case, either because the systems involved are not at all thermodynamical (e.g., economies), or—if thermodynamic considerations do apply—because these systems are thermodynamically open: Many of them import "order" from their environment (e.g., sunlight or food), and all of them export entropy to their environment (e.g., heat or waste).

Though self-organization eminently applies to living organisms, it is also seen in nonbiotic systems. Examples include crystallization, gravitational coalescence of cosmic dust to planets, the forming of galaxies, patterns in heated liquids, chemical compounds, living cells and organisms, the flocking of birds, evolution of life, ecosystems, brains and cognitive functions, artificial intelligence, and economies.

Relevance for religion and theology

In respect of religion, the idea of self-organization primarily presents a challenge because it suggests, as some physicists have been tempted to conclude, that the ability of cosmological, physical, chemical, and biological systems to organize themselves makes God as creator and director of the universe superfluous. Such conclusions may be premature, because many aspects of the theories about the origins of the universe and the origins of life are still highly hypothetical and uncertain; but, pointing to still existing gaps in those theories is not without danger for theology: Doing so may easily lead to a reintroduction of God as the filler of gaps. So, the real challenge for theology is to explore how the idea of God's agency with respect to the world, which is at the heart of the three monotheistic religions, can be related to the idea of nature's self-organization.

On the other hand, the idea of self-organization might give theology a chance to overcome its neglect—ever since theology's anthropological turn—of nature as a theological issue. According to modern theological insights, God is involved in human actions, mentality, morality, freedom, and finality, all of which the dominant mechanistic worldview regards as typically uncharacteristic of nature. A nearly total gap in theology between nature and God is the result. However, a number of scientists who describe certain natural processes as self-organizing, claim that the introduction of the concept of self-organization signifies a shift with respect to the accepted mechanistic paradigm, in the sense that to some extent these nonhuman processes might also be characterized in terms of finality and freedom. This new, nonmechanistic, view of nature might help theology to explore new conceptualizations of God's relationship to nature.

Apart from the question whether or not self-organization implies a paradigm shift, it is relevant to theology in another way. Studies of complex, dynamic, self-organizing systems involve themes such as order, chaos, waste and conservation, temporality, equilibrium, teleology, life and death, and consciousness, all of which also figure prominently in theological anthropology and in the religious interpretation of the world. It is therefore conceivable that the new insights arising from the study of complex, self-organizing systems may intensify and enrich the theological reflection on religiosity and religious interpretation.

See also AUTOPOIESIS; CHAOS THEORY; COMPLEXITY; EMERGENCE; ENTROPY

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PALMYRE OOMEN

SELF-REFERENCE

The concept of *self* is ambiguous; this discussion will limit *self* to its reflexive use. This reflexive usage appears when the knower is a premise of any explanation and an active part of whatever is to be known. Such a use of *self* is epitomized in the Copenhagen epistemology of complementary or exemplified in Heisenberg's Uncertainty Principle. This argues that at a subatomic level of investigation there cannot be any objectively neutral data to be considered. All data are observer conditioned.

More generally, self-reference is the nemesis of all rationally continuous statements. Cambridge thermodynamicist A.B. Pippard spoke of this as the "invincible ignorance of science." According to him self-awareness of any mechanical system is intrinsically impossible. In *The Emperor's New Mind* (1989), physicist and mathematician Roger Penrose argues that a computer can not answer self-reflexive questions such as "What does it feel like to be a computer?"

More abstractly, consider the analysis of adjectival phrases under the rubrics of autological and heterological as to whether they do or do not have the property they denote. *Short* is autological and *abbreviated* is heterological. In this self-referential exercise a paradox arises when one asks whether heterological is itself autological or heterological. Self-referential statements raise similar paradoxical issues. Willard V. O. Quine argues that statements such as "This statement is false" are not admissible as rational propositions since it can not be determined whether they are true or false. Science accordingly tries to avoid such self-referential statements, but such avoidance can eliminate the human factor all together. Self-referential statements are at the very heart of what it means to be human, which theologians as diverse as Søren Kierkegaard and Wolfhart Pannenberg make plain. Therefore self-referential statements are central to the theology-science dialogue.

See also COPENHAGEN INTERPRETATION; HEISENBERG'S UNCERTAINTY PRINCIPLE; PARADOX; PHYSICS, QUANTUM

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JAMES E. LODER

SELF-TRANSCENDENCE

Self-transcendence is a determining feature of all mystical experience. In the context of theistic mysticism, the self is to be transcended since it is considered to block the mystic from the divine influx, and to be a barrier to the goal of union with the divine. "No-one hears [God's] word and doctrine unless he has abandoned self," wrote the medieval Christian mystic Meister Eckhart (Kelly p. 220). And, according to the Hasidic master Dov Baer of Mezritch, "One must think of oneself as nothing and forget oneself totally. . . . If one thinks of oneself as something, . . . then God cannot clothe Himself in him, for God is infinite" (Matt p. 86). In the nontheistic teaching of Buddhism, belief in the substantiality and permanence of self is considered the root of delusion and the primary obstacle to achieving Nirvana. In Buddhagosa's poetic formulation:

> For there is ill but none to feel it;
> For there is action but no doer;
> And there is peace, but no-one to enjoy it;
> A way there is, but no-one goes it.
> *(Pérez-Ramon p. 11)*

In Vedanta, similar principles apply, although the terminology can be confusing. The everyday sense of self, the personal self or *I,* is regarded as illusory. The individual mind is merely an appearance, a portal to the true self, *atman,* the ultimate source and divine essence. The spiritual goal is achieved by transcending I and recognizing the self as the true witnesses—that which eternally observes and knows via the individual human senses and mind.

Scientific approaches

The experience of losing the individual bounds of self is also a hallmark of altered states outside the religious context, for example, in cases of neuropathology, drug-induced states, and trance. Scientific approaches have frequently assumed that a common explanatory cause may bridge differences of context. Thus, for example, the loosening of self-experience observed in some cases of temporal lobe epilepsy has led to the view that self-transcendence in religious contexts may be attributable to similar disturbances in these regions of the brain. In his 1987 book *Neuropsychological Bases of God Beliefs,* neuropsychologist Michael Persinger argues that micro-seizures in the right temporal lobe trigger "God experiences," as he calls them; Persinger has demonstrated that similar experiences may be induced by artificially stimulating these brain regions. Eugene D'Aquili and Andrew Newberg propose that the experience of self-transcendence follows a loss of input to the left parietal lobe, which, they argue, normally maintains the self-other divide.

These neurological views have been complemented by biological theories based on the evolutionary value of experiences of self-transcendence. It has been repeatedly observed that such experiences have a profoundly uplifting effect on mood. As the Psalmist writes, "From the straits I called to the Lord; the Lord answered me and set me in an expansive place" (Ps. 118:5). The biological argument holds that such positive shifts in mood aid survival value. Accordingly, self-transcendent experiences have adaptive value and the genes responsible for brain systems likely to engender them have been selected into the gene pool.

These biological and neurological approaches may be criticized for their reductionist slant, which fails to credit the claims of mystics and others that self-transcendence brings about a "higher" state. "Higher" in this context implies, first, access to a richer source of knowledge and, second, contact—or even union—with a realm distinct in metaphysical terms from the worldly reality.

The approach of cognitive psychology offers an understanding of the gnostic element here, for the self-system may be seen to limit the mental representation of knowledge. Thoughts and perceptions that enter consciousness are predicated on extensive preconscious processing of information, which is characterized by the absence of any reference to self. This preconscious processing includes a considerably wider breadth of information than that which finally enters consciousness. Becoming conscious is effectively a process of limiting the possibilities of meaning that were opened up preconsciously. The passage of information from preconscious to conscious is characterized both by this limitation of diverse meanings and by the integration of content with the cognitive representation of self. In this sense, the self can be understood as a limiting factor in the organization of the mind. The relevance of this to issues of self-transcendence lies in the suggestion that mystical practices curtailing the sense of self effectively prolong the preconscious stage. The mystic becomes aware of preconscious information processing, which appears "richer" than normal consciousness on account of the wider realm of meaning it supports.

This cognitive view of self as a kind of master referencing system for the mental representation of information accords with the mystics' own testimony. "On the knowing and feeling of self hangs the knowing and feeling of all creatures," states the *Cloud of Unknowing,* a sixth-century Christian contemplative text (Underhill p. 179). It is, of course, the "knowing and feeling of self" that the text urges the contemplative to transcend.

Conclusion

Cognitive science, as we have seen, can suggest a basis for the "higher" knowledge claimed via self-transcendence: The mental representation of self habitually locks the person into conventional ways of perceiving and thinking, and its dissolution opens the way to fresh and creative contact with ideas and objects. What, however, of the second meaning of "higher" noted earlier, namely contact with a metaphysically separate realm? This aspect of self-transcendence stretches the bounds of science since science is classically tied to our spatiotemporal realm. Nevertheless, an increasing number of psychologists argue that a broader view of science that will incorporate subjective experience within its remit is needed, especially because no current scientific procedures are able to disclose the ontology of consciousness. Along such lines, the reality of higher realms may be demonstrable through the kind of hypothesis-testing that is central to all science. Are there any real effects reported by those who follow practices promoting self-transcendence, as taught in the major mystical traditions? If, as most studies suggest, the answer is "yes," then serious consideration needs to be given to the higher sphere that practitioners claim to experience. As William James famously noted, "that which produces effects within another reality must be termed a reality itself" (p. 491).

See also EXPERIENCE, RELIGIOUS: COGNITIVE AND NEUROPHYSIOLOGICAL ASPECTS; MYSTICISM; NEUROSCIENCES; PSYCHOLOGY; PSYCHOLOGY OF RELIGION; SELF; SOUL

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BRIAN L. LANCASTER

SEMIOTICS

Semiotics is the study of signs and signification. Its subject matter includes the processes involved in both the production and interpretation of signs, as well as the classification of signs into various types and categories. The term itself has Greek roots (*semeiotike*) and a complex history of usage. Although it has become the word most commonly used to designate this area of study, ironically, it was employed by neither of the two great theorists who most decisively shaped modern semiotics. The American philosopher Charles S. Peirce (1839–1914) preferred *semiotic* (parallel to terms like logic and rhetoric) as a label for the study of the doctrine of signs, or frequently *semeiotic* to indicate its derivation from the Greek. And the French structuralist Ferdinand de Saussure (1857–1913) conceived of language as a particular system of signs, linguistics itself as being one part of the comprehensive science of signs that he called *semiology*.

Semiotics has sometimes been understood as a specific discipline, with its own method and determinate subject matter. In this case, the semiotician will attend most directly to the basic structure of the sign relation, the conditions of possibility for anything functioning as a sign of anything else. Here semiotics is closely related to philosophy (especially to inquiries in formal logic) and to theoretical linguistics. More typically, however, semiotics has been portrayed as a complex, interdisciplinary field of study, drawing not only upon philosophy and linguistics, but also with vital links to literary and communication studies, hermeneutics, the history and theory of art, anthropology, sociology, psychology, and even biology and the natural sciences.

In the earliest usage of the term, *semiotics* referred to a branch of ancient Greek medicine, the identification of physical symptoms for the purpose of making diagnostic inferences. During the same period, Greek philosophers were laying some of the theoretical foundations for the development of western semiotics with their analyses of the nature of signs, language, and meaning; especially important in this regard were the logical investigations of Aristotle (384–322 B.C.E.) and of the Stoics. In late antiquity, Augustine of Hippo (354–430 C.E.) developed what some scholars regard as the first systematic theory of semiotics in his treatises *De magistro* (The Teacher) and *De doctrina christiana* (On Christine doctrine). Augustine drew upon earlier Stoic deliberations, but generated new insight in an account that treated both nonverbal and verbal signs. His theory was essentially communicative, addressing not only the relation between signs and what they signify, but also exploring how signified meanings are conceived or brought to awareness in an interpreter's mind.

Medieval semiotics was heavily indebted to both the Aristotelian and Augustinian legacies. As it had with Augustine, semiotics took on a theological significance for the scholastics. A coherent doctrine of signs was essential for understanding the nature and efficacy of those special symbols of divine grace known as sacraments. At the same time, it was characteristic of the medieval outlook that the entire universe was perceived as signifying the divine will, just as any created effect is an index of its cause. The "book of nature" as well as the book of Scripture was a potentially fertile source of divine revelation, a general perspective that would serve as a stimulus to inquiry in the natural sciences as well as in theology.

Even while scholastic philosophy was on the decline elsewhere in Europe, in Spain and Portugal there were important advances in semiotics late in the medieval period and beyond. Here the writings of Peter Fonseca (1528–99) and John Poinsot (1589–1664) are particularly notable for their anticipation of modern developments. It was the British philosopher, John Locke (1632–1704), however, who first utilized the Greek term *semeiotike* to refer to that part of philosophy that deals with the "doctrine of signs." Its purpose is to explore questions about the nature of signs, their role in human understanding and in the communication of knowledge to others.

It was probably from Locke that Peirce borrowed the term when he reintroduced it into philosophical discourse late in the nineteenth century. But Peirce's pioneering work in semiotics was most clearly indebted to Aristotle and the scholastics, as well as to certain discoveries in modern logical theory. Peirce conceived of all of logic as semiotics. As such, it is a formal rather than an empirical science, concerned with what must be or would be true about signs in any and all cases. He developed a complex system and terminology for the classification of signs. The trichotomy of *icon* (a sign that signifies its object by resemblance), *index* (by a causal relation) and *symbol* (by virtue of some habit or rule) is the most well known, widely adopted component of that elaborate scheme. For Peirce, the proper object of study in semiotics was not the sign but rather *semiosis,* the entire process by means of which a sign stands for something to someone, a process schematized as the relationship among *sign-object-interpretant.* The realm of possible semiosis is unlimited. Peirce argued that there is no separate class of things that can be called "signs" since potentially anything can function as a sign. All thinking is in signs. Persons are themselves complex symbols. The universe, he claimed, is "perfused with signs," the rationale for his description of it as "God's great poem."

Independently but almost simultaneously with Peirce, Saussure was conducting his own semiotic inquiries. Saussure conceived of meaning not as the property of signs viewed as isolated units, but as something that they possess by virtue of their relationship to other signs in a complex system. Meaning is always contrast of meaning, the value of a sign being determined by comparison with other signs in the system. Each sign represents an indissoluble unity of perceived *signifier* and meaning *signified,* so that Saussure's dyadic model of semiosis differs from Peirce's essentially triadic account.

These two dominant strands of thought in modern semiotic began to intersect late in the twentieth century as poststructuralist thinkers, steeped in the Saussurean tradition, began increasingly to drawn upon Peircean concepts and arguments. At the same time, the potentially enormous significance of semiotic theory for theology and religious studies still remains to be assessed. Peirce's contemporary, Josiah Royce (1855–1916) had begun to adapt some of Peirce's ideas for the purpose of developing his own theosemiotic perspective, in his late work, *The Problem of Christianity* (1913). Peirce remains a rich source of inspiration for any future work in theosemiotic, as do the medieval philosophers whom he studied so carefully, thinkers for whom the religious importance of semiotic theory was paramount. While semiotic historiographers have focused their attention on a narrative that links ancient Greek with modern western thought, future inquiry will require a broadened purview. The resonance of certain Buddhist ideas, for example, with aspects both of poststructuralist thought and of Peirce's philosophy, has been observed by some scholars. This suggests that a Buddhist contribution to semiotics (typically neglected, perhaps, because of a perceived Buddhist suspicion of the religious efficacy of words and images) still needs to be evaluated.

See also AUGUSTINE; BIOSEMIOTICS; LANGUAGE

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SHINTO

Shinto is a practice of religious rites based on the Japanese polytheistic idea of *kami* (deity). The word *Shintō* literally means “Way of Kami.” Scholars of Shinto often maintain that it is the indigenous religion of Japan. Certainly Shinto has no obvious foreign origin, although there have been Korean and Chinese influences in the development of Shinto.

Institutional Shinto

Jinja Shinto (Shrine Shinto) is the institutional form of Shinto. *Jinja Honchō* (the Association of Shinto Shrines) in Tokyo is the administrating office for about eighty-thousand Shinto shrines in Japan. *Ise Jingū* (the Grand Shrine of Ise) in Ise, Mie Prefecture, which enshrines *Amaterasu Ōmikami* (the Sun Goddess), is considered to be the most sacred Shinto shrine. The emperor of Japan is considered to be the divine descendant of *Amaterasu Ōmikami* and the highest Shinto priest. The emperor’s most important religious duty is to pray to the *kami* for the prosperity of Japan, the happiness of the Japanese people, and peace in the world.

Shinto has no holy scriptures in the strict sense, but the mythologies collected in Japanese classics such as *Kojiki* (the *Record of Ancient Matters*), compiled in 712, and *Nihonshoki* (also known as *Nihongi,* the *Chronicles of Japan*), compiled in 720, are regarded as important texts. In many cases, the mythologies have political implications to justify the rule of the emperor, but they also have cosmological implications.

General phenomenology of Shinto

Shinto is one of the most widely practiced religions in Japan; for centuries the Japanese people have been practicing Shinto alongside Buddhism. Although there are some cases of syncretism, mostly a clear distinction is made between Shinto and Buddhism. Generally, Shinto concerns happiness and prosperity in this world, whereas Buddhism, for the Japanese, relates to the peace of deceased souls.

The grounds of a Shinto shrine are usually marked by a grove of tall evergreen trees surrounding a gateway called a *torii.* In the main building of the shrine, a *shintai* (divine object), which is supposed to bear the spirit of a particular *kami,* is enshrined. Typically, a *shintai* is an ancient-style mirror, which is contained in a special case. No one is allowed to view the *shintai* directly. With few exception, there are no images or statues of *kami.*

Most Japanese go to a Shinto shrine on certain occasions, often on New Year’s Day, to pray for the *kami*’s blessings. According to tradition, the prayer first washes his or her hands and mouth at a fountain located near the gateway. Then the prayer proceeds to the front of the main building, casts a few coins into an offertory box, rings the bells, bows twice, claps his or her hands twice, and bows one more time. The whole procedure takes only a few minutes.

A number of rites and one major festival are held annually at each Shinto shrine. In a Shinto festival, priests first solemnly offer prayers and foods such as rice and *sake* (rice wine) to the *kami,* thanking the *kami* and asking for the *kami*'s blessings. Dances and music are then performed for the *kami* and the people to enjoy together. The highlight of the festival is when portable shrines or floats are energetically paraded through the parish, usually carried by male parishioners. Many stalls that sell snacks or goods may be set up on or near the shrine grounds on the day of the festival.

A special ritual called *jichinsai* (Earth-pacifying ritual) is almost always performed by Shinto priests when construction begins on a new building or facility. It is believed that, without such a ritual, accidents may happen because the deities or spirits that dwell on the construction site become angry.

Characteristics of Shinto

Scholars of Shinto often point out that Shinto has no dogma, although some characteristics of Shinto have continued relatively unchanged during its long history. Muraoka Tsunetsugu (1884–1946) was one of the first scholars to outline the characteristics of Shinto thought. Stimulated and informed by Muraoka's studies, historian Delmer Brown reconsidered and reformulated the Japanese cultural paradigms. The following characteristics of Shinto are largely based on Brown, with a few revisions.

Vitalism. The scholar Motoori Norinaga (1730–1801) once defined *kami* as whatever seems strikingly impressive, possesses the quality of excellence, or inspires a feeling of awe. Certainly Shinto includes an animistic view of nature, but Shinto has a more distinctive characteristic. The *kami* enshrined in a Shinto shrine varies from a deity that appears in the mythologies in *Kojiki* or *Nihonshoki* to the spirit of a historical figure such as an outstanding emperor, feudal lord, or scholar. However, the *kami* is always believed to have mysterious power to create, enrich, prolong, or renew any form of life.

In other words, what the *kami* symbolizes is vitality, productivity, or fertility in this world. Shinto vitalism has roots in agricultural rites that may date back to the third or fourth centuries B.C.E. Even in modern times, people pray to *kami* for worldly happiness, prosperity, success, safety, or health.

Ritualism. In Shinto tradition, performing and participating in rituals has been given greater emphasis than believing and confessing a certain creed. Although theological treatises of Shinto were written as early as the thirteenth century, no established creed or orthodox dogma ever developed. It is more likely that the articulation of principles was intentionally eschewed than that Shinto failed to establish creed or dogma. Some rituals, such as the *Niinamesai* (Feast of New Rice Crops), which is performed by the emperor himself, are considered to be so sacred that the entire procedure and even the name of the *kami* involved are kept secret.

According to surveys, only a small percentage of Japanese confess that they believe in Shinto, but the majority of them visit a Shinto shrine on New Year's Day. Such data provoke some scholars to maintain that Shinto is a cultural custom rather than a religion.

However, State Shinto is an exceptional case. From 1871 to 1945, Shinto was the Rite of State, also called State Shinto. Toward the end of World War II, the sacredness and invincibility of Japan as the nation of *kami,* was so strongly believed that State Shinto became fanatical, leading many Japanese soldiers to suicidal attacks. Yasukuni Shrine in Tokyo enshrines the spirits of the soldiers who died for Japan and the emperor, not as souls of the dead but as *kami* (i.e., deities that have power to give vitality).

Particularism. Shinto is a national religion practiced only by the Japanese, including Japanese immigrants in other countries. With few exceptions, Shinto has had no interest in overseas missions or in universal principles or values that are considered valid for all human beings. Scholars of Shinto tend to emphasize the "uniqueness" of Shinto rather than its universality. Each *kami* enshrined in a local shrine is supposed to concern only the people in the local community. This particularism also originates in Shinto's development from agricultural rites focusing on the sacredness of the particular water source of each local community. Nonetheless, when Japan annexed Korea in the early twentieth century, the Japanese government built Shinto shrines in Korea and forced Korean people to worship Shinto *kami.*

Shinto and science

From ancient times, arts, sciences, and technologies, including philosophy, mathematics, astronomy, astrology, medicine, and alchemy, were continuously imported into Japan from China and Korea, and studied and developed in Japan in various ways. However, neither Shinto nor Japan gave birth to anything similar to modern science. In fact, the characteristics of Shinto discussed above, especially the animistic view of nature and the avoidance of establishing universal principles, may have stood in the way of the development of a modern scientific methodology or view of nature.

On the other hand, the Japanese studied and learned modern science earnestly and quickly once it was introduced. Some Japanese scholars started to study modern science when Shogun Tokugawa Yoshimune permitted the importation of nonreligious Western books in 1720. After the Meiji Restoration of 1868, the study of science was accelerated. Kōgakuryō (College of Science and Technology) was established in Tokyo in 1873 and was merged with Tokyo University in 1886. By the end of the twentieth century, Japan had become a world leader in science and technology. In that process, Shinto did not serve as an obstacle. Once science became associated with success and prosperity in this world, its study and application could be encouraged. Neither Copernican heliocentrism nor the Darwinian theory of evolution raised significant controversy in Japan, probably because the human being has no special status as the crown of creation in Shinto or Buddhism. In Shinto the human being is simply a harmonious part of nature.

The animistic element of Shinto that respects the vitality immanent in nature should certainly have the potential to make a positive contribution to human efforts to preserve the natural environment. Interdisciplinary conferences involving scholars of Shinto are occasionally held, although some feel that the politically conservative tendency of Shinto may work contrary to the efforts of environmentalism.

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MASAKAZU HARA

SIN

Sin is the condition or act by which a human person produces evil. Evil is suffering produced by either sin, disease, or accident. Suffering that leads to death and loss of relationship to God is the ultimate evil. The classic Christian list of seven deadly sins includes pride, covetousness, lust, envy, gluttony, anger, and sloth. Islam, led by the Qur'an, sees sin in terms of pride and opposition to God. Iblis or Satan provided the model for human sinning when he refused to obey God's command to prostrate himself before Adam. In an ancient Hindu-Buddhist myth of the fall a primordial disembodied mind living in the golden age descends into a physical body where desire, lust, passion, and covetousness prevail. Others follow, souls taking on flesh. Greed leads to stealing and violence, and the human soul becomes trapped in a physical world of temporal temptation from which it longs to escape to eternity.

Phenomenologically, evil is first experienced biologically as suffering. The most primitive awareness of sin takes the form of defilement, of external contamination deriving from physical contact with what is profane. Rituals of cleansing, usually with water, become the liturgical means for ridding the sinner of defilement. When this becomes internalized, defilement is associated with physical passions welling up from within, with carnal desires that tempt by threatening to overwhelm the rational mind by chaotic passion. Fleshly desires become identified with the lower nature, while mind or soul or spirit becomes identified with the higher nature. The higher nature is where the human will is lodged, and the highest form of sin is a freely willed act of evil.

The Hebrew and Christian scriptures advance no theory of sin, yet examples of sinning abound. Sins corrupt a person's whole heart, and total corruption requires total transformation or renewal by an act of divine grace. Sin applies to the individual heart as well as to a people or nation, warranting transformation of all things into a new creation.

Twentieth-century theologians and psychologists tended to associate the origin of sin with anxiety, anxiety understood existentially as feeling threatened by loss, threatened by dissolution into nonbeing. Death is nonbeing to a human, and the threat of death triggers in the human psyche a panic impulse to steal what it can from the imagined life force. In the moral sphere the pursuit of virtue becomes sinful, as those fleeing anxiety engage in self-justification and scapegoating. To define oneself as virtuous simultaneously requires assigning responsibility for the evil in the world to someone else, usually an enemy; this provides justification for decimating the enemy through gossip, lawsuits, war, or genocide.

Some religious theories associated with sin have been challenged during the era of modern science. The biblical story of Adam and Eve in paradise falling into sin, for example, has long been considered a historical event in Judaism, Christianity, and Islam, though interpreted quite differently. With the rise of evolutionary theory and deep time, the idea of a single pair of human progenitors has lost scientific credibility. No sinless paradise would be possible according to evolutionary theory because natural selection and survival of the fittest would necessarily apply at the point of origin. This dilemma has left theologians with two options. One is to deny acceptance to evolutionary theory, the path taken by scientific creationists in American Christianity and fundamentalist Muslims in Turkey. The other is to admit evolutionary theory and deny historicity to the Garden of Eden, the path followed by liberal Protestant Christian and Jewish commentators who see the Adam and Eve story as a myth describing everyday human activity.

A second challenge is indirect, the challenge to human free will from biological reductionism in genetics. During the era of the Human Genome Project, public belief in the determining power of DNA grew, and molecular biologists began to assign genes for not only physical traits but also predispositions to behavior. Antisocial behavior such as a propensity toward alcoholism, aggression, and violence were postulated as genetic in origin, as was homosexuality. Sociobiologists added the idea of the *selfish gene,* the principle that genes employ human bodies and human culture to insure their own replication through reproduction—their version of survival of the fittest. The fittest are those genes that bring their hosts to reproductive age. This idea allegedly explains why families and clans protect their own kin and are willing to prosecute war or even genocide against others. Moral behavior and religious practices became explainable as the result of genetic expression. Some scientists began to claim they had produced a biological explanation for original sin in the sense of an inherited propensity to survive to reproductive age even if it means perpetrating violence against genetic competitors.

The naturalistic question arises here for theologians. If theological interpretations of sin are compossible with genetic or other forms of biological determinism, one needs to ask: If something is natural is it good? If a doctrine of creation asserts that what exists presently in nature is due to God's will, then biological impulses even toward aggressive behavior must become normative. This is a theological version of what philosophers call the naturalistic fallacy: *What is* is *what ought to be.* However, much of traditional spirituality in Asia as well as the West has regarded human biological makeup as the source of misleading desire and dangerous passion; biological determinism would only increase religious resolve to pit the power of the spirit over the power of the flesh.

See also EVIL AND SUFFERING; FALL; GENETIC DETERMINISM; SELFISH GENE; SOCIOBIOLOGY

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TED PETERS

SINGULARITY

Singularities occur at the center of black holes. Because the General Theory of Relativity is a theory of space-time as well as of gravity, the consequences of the unbounded energy densities predicted by that theory at the end of gravitational collapse and at the start of the universe are catastrophic, for they imply an end to space-time itself. The possible history of an observer or particle simply comes to an end; physics breaks down, and space-time ceases to exist. It is difficult even to begin talking about this situation, for even the word *exist* ceases to have meaning. It is unclear if quantum gravity theories will avoid this implication.

An unresolved problem pertaining to singularities is whether gravitational collapse can lead to a *naked singularity,* that is, one that will be visible from far away and so can influence events in the outside world. The contrary of this possibility is that a naked singularity can only lead to a black hole, where a singularity occurs but is hidden from the outside world by an event horizon.

See also BLACK HOLE; COSMOLOGY, PHYSICAL ASPECTS; GRAVITATION; RELATIVITY, GENERAL THEORY OF; SPACE AND TIME

GEORGE F. R. ELLIS

SKYHOOKS

The metaphor of skyhooks, typically used pejoratively, is a label for explanations that appeal to powers transcending nature, a supernatural beyond the secular order. The idea is similar to *deus ex machina* interventions in ancient Greek plays, where a god was brought in from above by stage machinery to resolve a complicated plot, often unconvincingly. In his 1995 book, *Darwin's Dangerous Idea,* Daniel C. Dennett argues that Darwin replaced "skyhooks" with "cranes," mechanistic forces building up over evolutionary history, not mind-like designing, which is only a resulting appearance. However, with genetics, a cybernetic model of DNA that encodes an evolutionary increase of information suggests a more cognitive account, indifferent to whether the novel information appears from above or below. The fundamental issue is whether naturalistic explanations are complete. This especially the case for those explanations featuring the emergence or superposition of genetic complexity with escalating cognitive powers, eventuating in human minds.

See also EVOLUTION; GENETIC DETERMINISM

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SOCIOBIOLOGY

In the *Origin of Species* (1859), Charles Darwin argued that the main mechanism of evolutionary change is a process he called *natural selection.* More organisms are born than can survive and reproduce, bringing on a struggle for existence. Given naturally occurring variation, there will be a differential reproduction—some reproduce, some do not—akin to the artificial selection practiced by animal and plant breeders, with the end result of permanent change. In a drought, animals able to do with less water are "fitter" than those that need to drink more. Moreover, organisms will be adapted: they will show the organic contrivances highlighted by those natural theologians intent on showing that there is a designing God. Examples include the hand and the eye and such like. Darwin applied this mechanism to many different fields of biology, including paleontology, embryology, systematics, and biogeography. Behavior was included in Darwin's theory, for he saw that what an organism *does* is as crucial in the struggle for existence as what an organism *is.* There is little point in having the physique of Tarzan if you have the mind of a monk.

The evolution of sociobiology

Darwin was particularly fascinated by certain social behavior, especially that of ants, bees, and wasps (hymenoptera), where an organism sacrifices itself for the good of the group. It seems prima facie that such behavior is at odds with the kinds of self-centered acts that would lead to individual success in the struggle for existence. Darwin understood how the sterility of a worker ant, for example, might be transmitted through fertile nest members—the domestic world had shown how one can select vicariously, as it were, for characteristics in animals that will not themselves breed—but he could not see how sterility itself would come into being. Darwin was convinced that all selection must be for the individual, not the group; sociality—worker sterility, in particular—was a major challenge. Although Darwin concluded that one can regard the colony (of ants and so forth) as a kind of superorganism on which selection can operate as a whole, he never really resolved the problem of sociality.

For a number of reasons, the study of the evolution of social behavior lagged after Darwin. First, the rise of the social sciences with their interests in behavior discouraged biologists from addressing the subject. Social scientists tended to experiment on rats and mice, to generalize, and then to conclude that transpecific differences were irrelevant. Social scientists also tended to work in artificial situations and so were generally not interested in natural behavior, and unable to recognize it when it appeared. Second, in the first half of the twentieth century, the racial doctrines of the Third Reich convinced many that the study of social behavior from a biological perspective would lead to claims about the innate behaviors of humans, with consequent belittling of the worth of those not in one's own group. Although some protested that such fears should not tar all biological studies on behavior, the damage was done and remained for many years after the Second World War. Most importantly, no one really knew how to move theoretically beyond Darwin so that social scientists could study social behavior while staying true to the principles of natural selection. The social sciences needed new approaches that eschewed group selection, allowing evolutionists to dissect nature and drag forth its secrets.

Kin selection. Breakthroughs came in the 1960s. A number of models were devised that allowed scientists to study social behavior in animals, while staying true to the individualist or "selfish" nature of selection. Notable was the theory of *kin selection,* devised by the English biologist William Hamilton, who showed that close relatives have a biological interest in helping each other because by doing so they indirectly support the success of their own units of heredity, their own genes. Hamilton applied this thinking to the ants, bees, and wasps, pointing out that these animals have a peculiar breeding system, where only females have fathers (males being born from unfertilized eggs). This means that sisters are more closely related to each other than normal. In the usual case (e.g., humans), mothers and daughters are 50 percent related, as are sisters. In the hymenopteran case, a female gets the same genetic input as her sister from their shared father and then 50 percent input from their shared mother. Thus sisters are 50 percent and one-half 50 percent (75%) related, whereas mothers and daughters are just 50 percent related. It is in a worker's reproductive interests to raise fertile sisters rather than fertile daughters—an activity that is aided rather than hindered by the worker's own sterility. There is no need to treat the colony as but one unit for one can see individual interests being played out in this, the most integrated and harmonious of social situation.

Reciprocal altruism. Other models were devised, including one that Darwin himself sensed, even if he did not fully articulate it. *Reciprocal altruism* works on the principle that when an organism gives help, it is entitled to receive help when needed. Reciprocal altruism can work even among non-relatives, or—at the extreme—across species. Certain fish are major predators, but they tolerate other types of fish that swim directly into their mouths and pick out harmful bacteria and fungi on their gums. The predators practice dental hygiene and the cleaners get a good meal because the larger fish does not swallow the smaller fish in its mouth. Everyone benefits.

Evolutionary equilibrium. Evolutionists turned to game theory in cases where participants adopt various strategies to succeed in the light of the fact that other players (in biological terms, other members of the species) are also trying to succeed. In *The Selfish Gene* (1976), a provocative popularization of this theory, British biologist Richard Dawkins showed how certain evolutionary situations achieve equilibrium, or reveal what he called "Evolutionary Stable Strategies," when no one member of the group can achieve more than limited benefits, given the conflicting interests of the group. To take one of Dawkins's examples, consider a group with two kinds of members. Some members of the group are "hawks," who in any potential conflict situation are aggressive and will fight if need be. Others in the group are "doves," who always run if a fight looms. One might assume that the hawks would dominate and that selection would produce a population without any doves. But this is not so. A hawk's encounter with another hawk always leads to a fight, which may end with one hawk injured or dead. Doves, however, never get beaten up because they run. So, on average, there is a cost to being a hawk. But doves cannot dominate either, because, on average, there is a cost to being a dove. Hawks always win confrontations between a hawk and a dove. The birds of the group therefore end up in a balanced if uncomfortable midpoint, with neither hawks nor doves able to increase their representation at the expense of the other.

Armed with these theories, naturalists and experimentalists turned to the larger world to determine if they could understand the social behavior not just of insects and fish, but of more complex animals like birds and mammals. The widest range of topics was covered. Notable was a study (led by Cambridge biologist Tim Clutton Brock) of red deer on an island off the coast of Scotland that showed how male deers strive to capture harems and will compete (or not) as it proves to be in their interest, and how female deers, which seem to be controlled by males, will in turn employ tricks and strategies to improve their reproductive options and results. A female wants her offspring, particularly her sons, sired by a male who will pas on his superior breeding qualities. Another study (conducted by Cambridge biologist Nicholas Davies) looked at the dunnocks (hedge sparrows), a bird that has the widest of breeding patterns—*monogamy, polygyny* (one male, several females), *polyandry* (one female, several males), and something primly referred to as *polyandryny* (group sex, with several males and several females). By doing DNA fingerprinting on the birds and their offspring, researchers could trace relationships, demonstrating just how much behavior was controlled by reproductive interests. This study revealed that dunnocks do not raise chicks with whom they have little reason to think they have real blood ties. Moreover, a dominant male (an "alpha") will tend to spend more time chick rearing and to have more offspring than a lesser male (a "beta"). Another study in Holland (reported by ethologist Franz de Waal) looked at relationships within a troop of chimpanzees—how males needed female help to dominate a situation, and how different alliances would be formed according to different interests. Two weaker males might prefer to gang up to defeat a stronger male, rather than simply acting individually.

Edward O. Wilson. Research went ahead with speed and enthusiasm, and before long, the science of the evolution of social behavior—now called *sociobiology*—was ready to take its proper place in the Darwinian family, along with paleontology and the other subjects. But controversy loomed. Darwin had wanted to apply his ideas to humans, and in the *The Descent of Man* (1874) he did just that, as did Darwinian scientists who came later, in particular, Harvard entomologist Edward O. Wilson. In a major overview of the field, *Sociobiology: The New Synthesis (1975),* and later in a work addressing the human species, *On Human Nature (1978),*Wilson argued that nearly every aspect of human life and nature is a function of biology, or, more accurately, the genes as fashioned by natural selection. Sexual differences, family structures, religion, warfare, language, and much more, are the end result of natural selection working on the units of heredity. Even homosexuality could be biologically caused, as gay and lesbian members of the family aid close relatives, like sterile mammalian workers at the nest. Moreover, argued Wilson, while humans may be able to change some things, biology will be resistant and, in many respects, people are locked into being what they are. Utopian plans for change would be counterproductive.

Early objections to sociobiology

As expected, there were many objections to the new field of sociobiology. Social scientists became tense because they felt that biologists were poaching on their domain. Rather than accepting biology as a complement or an aid to social science, they saw it as a threat and feared sociology would vanish and sociobiology (social-group division) would take its place. Feminists abhorred what they considered a direct attack on their ideology, which held sexual differences and family structures to be purely cultural rather than biological constructions. Darwin was painted as the archetypical Victorian male chauvinist, and sociobiology was seen as an excuse for the status quo that oppresses women and children. Marxists, and this included some eminent biologists, felt that a biological approach was a travesty of the truth, because it pretended that evolution and natural selection had accomplished what was truly a function and result of economic deprivation. Their ideological ancestor, Friedrich Engels, had inveighed against a reductionist approach to understanding, and human sociobiology was the worst of all possible offenders.

Interestingly, the one group that might have been expected to explode—those members of the Christian community interested seriously in science—was far more receptive. Creationists, of course, would have nothing to do with any evolutionary science, and they fully enjoyed the controversy that pitted evolutionist against evolutionist. More moderate Christian thinkers reacted in a different way. Although they hardly welcomed human sociobiology with unalloyed joy, they could see that the new science was a serious approach to serious problems, and responded in this spirit. Even Christians drawn to feminism and Marxism realized that there was more to life than simple matters of culture, tradition, and economics. God, they argued, is not a social constructivist.

Later interpretations

By the dawn of the twenty-first century, much of the dust had settled. There is certainly no question that some of the early enthusiasts for sociobiology let their imaginations outstrip the evidence, filling in gaps with creative intelligence. But some of the most interesting work has come from evolutionists who have actually turned biology on its head. Sarah Hardy, for instance, has argued that female humans conceal ovulation, thereby ensuring that males have to stay around and participate in child rearing—if they do not, they cannot be sure of paternity. In other words, in good feminist fashion, she argues that the evolutionary scales are balanced, and may, if anything, be tipped in favor of women. Others have argued that sociobiology underlies the unity of the human community, thus belying fears of racism. People can, of course, interpret biology and form prejudices as they will, but there is no reason for thinking that biology supports or contains such prejudices.

In many other ways, human sociobiology transcends the parody portrayed by the critics. Typical of modern sociobiological research (often now hidden under less flamboyant and provocative names like *human behavioral ecology* or *evolutionary psychology*) is a careful study of homicide by the Canadian researchers Martin Daly and Margo Wilson. They have shown that murder falls into stable patterns, which lend themselves to a sociobiological interpretation. For example, the killing of children by parents (other than infanticide, which follows its own rules) is almost always perpetrated by step-fathers rather than biological fathers. This is a pattern very much in line with the rest of the animal world, where it is well-documented that males moving in on a new female will attack her already-existing young, so that their own new offspring get more attention. Paradoxically, when Daly and Wilson began their study, they could find no firm evidence against which to test their hypotheses. Authorities thought it prejudicial to reconstituted families to collect statistics on whether or not family violence involved step-parents or biological parents. It was only when Daly and Wilson insisted on the collection of the data, that the patterns emerged.

Implications for religion and philosophy

Sociobiology suggests much to the philosopher or the theologian interested in the deeper questions about human nature. Traditional approaches to evolution and ethics—so-called social Darwinism—argue that moral codes follow from the need to cherish and promote the evolutionary process. Thus, British philosopher Herbert Spencer endorsed laissez-faire economics in the name of evolution, seeing it as part of the struggle for existence in the human world. Just as in nature the weak fall because they are inadequate, so in society the weak fall because they are inadequate; this, argued Spencer and his fellows, is nature's way and to try to prevent it is to lead to decay and degeneration. Most sociobiologists avoid arguments of this type. Following more sensitive thinkers, like Darwin's "bulldog" Thomas Henry Huxley, sociobiologists refuse to identify the "evolved" with the "good." They see that although evolution can produce the worthwhile, evolution can also produce the absolutely horrible. Although Daly and Wilson think that child killing may be biologically motivated, they stress that it is not moral in any sense. Their work indeed is intended to throw light on the problem, so that people might change or control such behavior. Male lions and lemmings may kill the young of other males, but this is no reason for humans to do likewise.

There are, however, other ways to tackle issues of morality, while still bringing sociobiology to bear. First, one might argue, as many do, that humans are social animals in the extreme, and as such need mechanisms to get on with other humans. If humans did not have adaptations to protect against disease—as native Tasmanians did not—the human species would soon die out. The same is true of behavioral and motivational adaptations. By nature people are selfish—that is a direct consequence of the struggle for existence— but this selfishness, untamed and unmodified, would lead to disaster in social situations. People would quarrel and fight nonstop and be unable to work together. So they need special adaptations to overcome this counterproductive consequence of natural selection. But what could these adaptations be? Humans are too complex simply to have social sentiments hardwired in, like ants. Apart from anything else, simple hardwiring gives no room for reflection and regrouping when things go wrong or when facing new or unexpected situtations. Humans need something more subtle than the simple rules of social behavior followed by the hymenoptera. Here, argue sociobiologists, is the place for a moral sense, something that humans have innately (that is, put in place by selection and backed by the genes) that allows them to meet social demands and to work together with other humans. People have a sense of moral obligation that they *ought* to help others (and equally a sense of moral obligation that when they are in need, others *ought* to help them). It is something that aids people in social situations, and at the same time is obviously an instrument with sufficient subtlety and flexibility to allow people to adapt as situations and environments change. In other words, biologists of human social behavior argue that ethics has been put in place by human biology to make people good cooperators. Ethics is an adaptation.

The atheistic interpretation. What implications does this discussion have for the foundations of ethics (what philosophers call *metaethics*)? If ethics, the human sense of right and wrong, is an adaptation, is it thereby no more than a subjective sentiment, on a par with a liking for certain foods? The answer depends on one's theological commitments. Atheists and skeptics will probably conclude that there are no foundations, that ethics is simply an epiphenomenon of the genes, with no more ultimate meaning than any other adaptation like eyes or teeth. However, the tendency toward ethical behavior is not simply a subjective sentiment like a fondness for ice-cream. For a start, it has to be universally shared by other humans (except perhaps psychopaths), otherwise it would not function. Moreover, subjective emotion or not, it has to have an illusion of objectivity—of a foundation—otherwise it would simply collapse, as people decided to cheat and look after themselves alone. A conscience is essentially a part of the moral sense, even if (especially if) it is just an adaptation like everything else. But ultimately, the nonbeliever thinks that there is nothing to ethics but a naturalistic explanation of where it came from and why it has the hold on people that it does.

The Christian interpretation. What if one is a Christian or a member of any other theistic religion, however? Can this rather bleak philosophy take on a different, more hopeful and fulfilling hue? If one is a believer, one can (and must) surely interpret the situation as God's way of instilling an ethical sense in humankind. After all, the believer has to agree that God has instilled an ethical sense, and if one is an evolutionist then surely the sociobiological scenario is as plausible a scenario as any other. In fact, the Christian—certainly the Christian who takes seriously the teaching of Thomas Aquinas—knows this already. Natural law is something imposed upon us by the way that God has created humans. Human sexuality is intimately bound up with the fact that (in the first place) there are two sexes, and that to fulfill this sexuality people have the various emotions and organs that they do. Moral dictates follow from the nature of this creation. Promiscuity, for instance, is immoral because it is a violation of the natural—that is, God-made and God-ordained—bonds of erotic love that can and should exist between two people exclusively. For the theist who accepts sociobiology, ethics is part of creation, and the emotions and reasons that constitute it are very much part of the God-made natural order. Hence, inasmuch as one's moral sense (and the awareness to which it leads) is something natural, it is something to be cherished and obeyed and respected by God's creatures.

Sociobiology and original sin. But what about original sin? No one who has lived through even part of the past century can be insensitive to this issue, and those who were wont to downplay its significance in theology are now surely in the minority. How else does one—how else does the Christian—explain the evils of national socialism and all of the other vile movements of the past hundred years? The idea that humans are in some sense tainted—not wholly bad but with a dark side to their natures—is pressing on the nonbeliever and obligatory for those who think that Jesus was the Christ, the Son of God who died on the Cross for the sins of humans. The traditional position, that of Augustine of Hippo, is that the sins of Adam and Eve are transmitted to us all through sexual intercourse—people inherit their faults. No evolutionist can take this literally—indeed, it is unlikely that Augustine, who was sensitive to the development of knowledge and who had full awareness of the need to interpret the Bible allegorically, would now interpret the Adam and Eve story literally. He too would feel a need for revision.

A sociobiological approach shows a way of updating the belief in original sin—a way that takes modern science seriously and yet in no sense denies or belittles the significance of such sin. Sociobiology starts with the fact that humans are destined to be selfish animals—that is the way of natural selection. Group selection is no longer a viable mechanism, and all must be interpreted in the light of advantage to the individual. If people were not selfish—if they did not take for ourselves—then they would have become extinct long ago. But at the same time, sociobiology stresses that humans are social animals that need to get on together. So humans evolved ethics. But humans are not locked in blindly, like ants. They have moral sentiments, and though they may not have much choice about the moral sentiments—a fact that no one, other than existentialists at their most extreme, has ever denied—they can decide whether or not to obey the sentiments, as it pleases them. And sometimes it does please people, and sometimes it does not. Sometimes people continue in their selfish ways even though others would suffer, and sometimes they listen to conscience and do the right thing—sometimes indeed they do not even have to listen to conscience before doing the right thing. In other words, humans are an ambivalent mixture of good and ill—sometimes doing the kind and charitable thing, and sometimes failing in their obligations and duties. And humans are this way in their deepest nature, something they inherit rather than create anew. And that surely is precisely the Christian position on original sin. People are tainted. They cannot escape this. It is inherited as part of human nature. But humans have the abilities to do the right thing, to act against this side to their nature. Sometimes they do, and sometimes—all too often—they do not.

Freedom and determinism. Finally, one must address the question of freedom and determinism. It is an absolutely crucial part of Christian, as well as Jewish and Muslim, belief that people are made in the image of God, and therefore have the freedom to choose between good and ill. God may know what people will do, but God does not constrain them in what they will do. Each person's faults are his or her own responsibility. Can such a conception of freedom be reconciled with human sociobiology, a discipline that some critics complain is committed to genetic determinism? Those who dislike human sociobiology argue that sociobiologists portray humans as marionettes on the strings of the genes, with no more power of choosing right or wrong than the puppets Punch and

Judy have of living in domestic harmony. People are as clockwork, set up and simply set to run. The wife beater resorts to violence because he is male and that is the way of men. The child whines because it is a child and that is the way of children. The racist has genes for xenophobia and is no more at fault that the person with Down syndrome who cannot pass an intelligence test. Biology is destiny, and that is the end to freedom.

A more thoughtful approach, however, shows that Christian conceptions of freedom and sociobiological conceptions of determinism are not necessarily contradictory and can indeed be complementary. On the one hand, the Christian recognizes that freedom does not mean stepping outside of the laws of nature, for in that direction lies randomness or madness. Augustine, again, saw that true freedom means working according to human nature. God is free and yet cannot do ill. It is against God's nature to do ill. Likewise, people are free, but what they do is part of their nature. That is why God knows what will happen even though God does not control or will it. People are free to kill their children and yet most could no more do so than they could jump over the Atlantic Ocean. They are free to refrain from boasting, and yet could no more do so than they could climb Mount Everest. Conversely, for all the talk about determinism, the sociobiologist recognizes, in fact insists on, a dimension of human freedom. Ants are hardwired to do what they do. They have no choice. But humans are not hardwired to do what they do. They do have a choice; they must have a choice if they are to function as the complex social animals they have evolved into. Humans may be part of the causal nexus, but they have a dimension of freedom denied to rocks or lower animals and plants. If ants are like cheap rockets shot off and then, once fired, beyond further control, humans are like expensive rockets with feed-back mechanisms enabling them to respond to changes in the target. In short, the Christian recognizes that human freedom takes place within rules and restraints, and the sociobiologist recognizes that human determinism is open to dimensions of choice and alternative action. Why then should not the Christian and the sociobiologist work together to find a meeting point on these issues, harmony rather than conflict? Far greater gaps exist between Christians and their critics than between sociobiologists and their critics.

Conclusion

Other issues could be raised, and some are still far from resolution. If evolutionary theory is true, then presumably human minds—in line with everything else biological—are part of gradual development in time. Yet Christians have tended to see minds (and souls) as a sharply demarcated phenomenon—either humans have them or they do not. Animals do not have souls; humans, all humans, do. There is a brittle break in nature at this point. This is certainly a place where some compromise is necessary if consistency is to be achieved. There is surely much work and serious rethinking still needed on the connection (if there is one) between the human mind, either the Christian human mind or the sociobiological human mind, and the teachings about the nature and existence of the immortal soul. But these and other problems are challenges, not road blocks. Certainly the larger Christian community was correct in its intuitions when, on the arrival of human sociobiology, it took a position of welcome, albeit guarded welcome, rather than of hostility and rejection. All human understanding is grist for the theological mill, and sociobiology is no exception.

See also BEHAVIORAL GENETICS; DARWIN, CHARLES; DETERMINISM; DNA; EUGENICS; EVOLUTION, BIOCULTURAL; EVOLUTION, BIOLOGICAL; FREEDOM; GENETIC DETERMINISM; GENETICS; MEMES; MUTATION; NATURE VERSUS NURTURE; SELFISH GENE; SIN

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MICHAEL RUSE

SOCIOLOGY

Although it may be argued that all the sciences can trace their roots in some measure or other to religion inasmuch as religion dominated institutional scholarship well into the nineteenth century, sociology is unique in that its formal origin was actually cast in the context of a new putatively religious movement. The term *sociology* was coined by Auguste Comte in his *Cours de philosophie positive* (1830–1842); for Comte *la sociologie* was nothing less than the capstone of the new religion of positivism, replacing older theological or philosophical principles for social organization with those of science. Sociologists were to be nothing less than the "high priests" of this new moral order. The coining of a term does not a science make, however, and the fact that "sociology" received relatively quick and widespread acceptance among diverse constituencies suggests that Comte created an acceptable label for an intellectual movement that was already in process in the nineteenth century—namely, the two-fold premise that human social behavior could be studied with the same investigative canons that are applied to other "natural" phenomena and that human social behavior was irreducible to psychological or biophysical explanations.

Although the explicitly religious expression given to sociology went with Comte to his grave, virtually all of the leading lights of early sociology devoted considerable attention to aspects of religious life—what religion is, how it works, how it came into being, why it persists or recedes. These questions were among the most burning that early sociologists confronted. Karl Marx, Émile Durkheim, Max Weber, Georg Simmel, Herbert Spencer, and others whose work spanned the transition from the nineteenth to the early twentieth centuries tried to comprehend the role of religion within the larger sociocultural setting that makes human existence possible. Each realized that religion was a uniquely human experience, without any analog in the animal world, that, in the past at least, seemed to have had a controlling effect on the way people lived.

These early sociologists provided different images of religion, raising different kinds of questions. Through these images, however, runs a single theme—religion and social change. Marx throughout his work saw religion as a significant part of structural systems of oppression. Durkheim in his crucial work *The Elementary Forms of the Religious Life,* published in 1912 at the culmination of his career, saw religion maintaining social order or equilibrium. Weber, in a brilliant series of essays known as *The Protestant Ethic and the Spirit of Capitalism* (originally published serially in German from 1904 to 1905, and issued in English as a single volume in 1930), saw religion as a vehicle for enabling social change.

Sociology in America: the early years

Although the roots of sociology are certainly European, the discipline came to fullest flower in the United States. Its course was by no means singular. The first book to use the word in its title was the *Treatise on Sociology* (1854) by the apologist for slavery Henry Hughes, who with George Fitzhugh and Stephen Pearl Andrews attempted to formulate an American sociology according to a peculiar reading of Comte that would hardly be recognizable by anyone in the field today. The Confederate loss of the American Civil War and Hughes's death in it largely ended this line of development. Of much more sustained influence were the writings of Herbert Spencer, and it was William Graham Sumner, a Spencerian, who taught the first course in sociology ever offered in the United States at Yale in 1876. Sumner, who was ordained within the Episcopal Church (though he apparently did not officiate once at Yale), was an enormously popular professor: "no one was supposed to have 'done' Yale as a gentleman should," Albion Small recorded in 1916, "without having taken at least one course with 'Billy' Sumner" (p. 732).

A further influence was that of Christian sociology, an American variant of British Christian socialism. Explicitly introduced by J. H. W. Stuckenberg's *Christian Sociology* (1880), the Christian sociology movement experienced a groundswell of interest in the last two decades of the nineteenth century, particularly through the Chautauqua movement and "summer schools" at Oberlin College in Ohio and Hartford Seminary in Connecticut. Christian sociology might well have become the dominant mode in America society had it not been for a series of circumstances, ironically arising out of this very movement, that led to Albion Small establishing the first free-standing department of sociology in the United States at the University of Chicago in 1893.

Brought to Chicago by Chautauqua-inspired, Rockefeller-funded William Rainey Harper, Small walked a series of tightropes to shape a distinctive American sociology. First, he courted Lester Frank Ward, termed by Samuel Chugerman in his 1939 biography "the American Aristotle," in many ways the first American sociologist in his own right, who only late in his life received a university connection (at Brown University in Rhode Island). Ward was important to Small because Ward offered a Comtean alternative to the proslavery apologists that at the same time moved away from Sumner's exposition of Spencer's evolutionism—although there were, in fact, connections between Ward and Spencer through the Unitarian theologian M. J. Savage. Second, in what may well have been his most important single institutional step, Small founded the *American Journal of Sociology* in 1895, which became his personal implement for the operational definition of sociology in America and the invention of its history. Third, Small simultaneously courted and distanced himself from Christian sociology by enlisting the liberal University of Chicago theologian Shailer Matthews to write a series of articles in the first issues of this new journal, which effectively redefined Christian sociology to exclude the positions of the most ardent advocates of Christian sociology. Fourth, he built an empirical sociological style that came to define American sociology for the first half of the twentieth century: sociology of the Chicago School.

In addition to a large collection of volumes dealing with a variety of issues generated by the burgeoning urban life of Chicago, the Chicago School also initiated a distinct American theoretical approach, most generally known as *symbolic interactionism,* through the work particularly of George Herbert Mead, William Isaac Thomas, and Charles Horton Cooley. Although symbolic interactionism has become a diversified cluster of approaches, associated with universities where its different proponents have settled, the perspective continues to find its roots in the work of these scholars and has been revivified in social constructionist or situationalist theories among contemporary sociologists.

American sociology: tradition and transitions

By the end of World War II, American sociology dominated the profession throughout the world. In many respects, American sociology *was* sociology. World War I wreaked havoc among European sociologists. A number of the most promising young French sociologists were killed in the war, and Durkheim, Simmel, and Weber died of natural causes within three years of each other at the end of the war. The Great Depression, followed by the next war and the Nazi pogroms of the Jews, largely devastated the European intellectual currents most sympathetic to sociological scholarship. Some of those scholars managed to escape to the United States from the ravages of fascism and became part of the movement toward American dominance of the field.

During this period, American sociology sought to distance itself further not merely from religion, but from applied concerns in general. The social conditions of the depression followed by the exigencies of war made glib social pronouncements vacuous, while increasing the demand for "hard data" upon which to devise and implement programs for change. The depression and World War II served to underwrite empiricism, as various funding agencies poured money into research.

Though not necessarily in agreement themselves, figures such as Harry Elmer Barnes, Luther L. Bernard, F. Stuart Chapin, William Fielding Ogburn, and especially George Lundberg, who answered his rhetorical soteriological query *Can Science Save Us?* (1947) with unfettered assurance, nevertheless produced a more rigorously empirical discipline, with little use for higher-order analyses. Under Samuel Stouffer, a multivolume *American Soldier* series beginning in 1949 was produced, innovations were made in content analysis through captured enemy documents, and Paul Lazarsfeld led studies at Columbia, a historic center of sociological empiricism, on the effects on public opinion of radio propaganda.

Small died in 1926, and his mantle at Chicago fell to Robert E. Park. Although Park is arguably more distinguished than Small in his lasting intellectual contributions, times had changed sufficiently—in part a testimony to the success of Small's enterprise—so that a single institution could not expect to exercise the kind of disciplinary hegemony that Small had managed to effect at the turn of the century. The final sign of the dehegemonization of the Chicago School was the establishment of the *American Sociological Review* as the "official journal" of the American Sociological Society (now the American Sociological Association, hence ASA) in 1935. The *American Journal of Sociology* continues to be published, and vies with the *American Sociological Review* in various ranking systems for the "most important" in the profession.

The Chicago School was by no means out of touch with the profession, however, and in the 1930s brought a young, European-educated Harvard professor named Talcott Parsons to discuss the role of theory in research. Later, Chicago would bring Parsons's sometime coauthor Edward Shils to its faculty. Revisioning the field and in so doing founding Harvard's Department of Social Relations, Parsons's functionalism, a unique attempt to merge Durkheim and Weber, came to dominate American sociology for the larger part of two decades, reaching its quintessence in Kingsley Davis's triumphalist presidential address to the ASA in 1959: "The Myth of Functional Analysis as a Special Method in Sociology and Anthropology." Moreover, a friendship that grew between Parsons's former student Robert K. Merton and Paul Lazarsfeld as they both served on the Columbia faculty (1954) did much to heal the rift between empirical and theoretical sociological styles.

In that process, Talcott Parsons—particularly, but certainly not only, as the translator of the Protestant ethic essays—also "brought religion back in" as a field for sociological inquiry. But because he did it in the context of an attempt to synthesize Durkheim and Weber, who had far more differences than commonalities, he created an odd construction of religion that focused on a particular historical mode of religious organization that delegitimated religion as an independent variable. The outcome came to be articulated under the rubric of *secularization theory,* though as this ideology was recrafted it turned from something largely positive in Parsons's specific use to something negative, particularly at the hands of popular essayist Will Herberg.

Contemporary theory

Although Parsonian functionalism remained the primary mode of sociological analysis into the early 1960s, it was increasingly challenged by neo-Marxist sociologies. Columbia sociologist C. Wright Mills—who, ironically, was the other major American importer of Weber—and German sociologist Ralf Dahrendorf became two exemplars of the new styles of analysis. Mills was strident and politically active; Dahrendorf was a more dispassionate exemplar of leftist theory. The succeeding decades brought diverse elaborations of alternative themes in the work of such figures as Pierre Bourdieu, Anthony Giddens, and Immanuel Wallerstein. Because the reaction against Parsons's functionalism had Marxist leanings, sociology again distanced itself from religion. This breach was to some extent restored by the emergence of Latin American liberation theologies, which used Marxist categories for Christian ends.

Far more significant to the field as a whole, however, was the collapse of the Soviet system beginning in 1989 and the role of religious actors on the global sociopolitical scene as early as 1979. It could be argued that sociology at the beginning of the twenty-first century is in a state of theoretical fragmentation and fermentation, as no single paradigm exercises disciplinary hegemony, and critiques of "grand narratives" based on postmodernist understandings make disciplinary consensus difficult to achieve. As an alternative to postmodernist nihilism, however, globalization theory, as evidenced, for example, in the work of Roland Robertson, offers itself as a viable construct for integrating diverse social phenomena and expressions. Considering the world (or globe) as the unit of analysis, globalization theory takes some of its cues from Parsons in its differentiation between the universal and the particular as a major axis for understanding social action, but it draws toward conflict theory inasmuch as it recognizes the importance of particularistic universalisms and universalistic particularities as dynamics of destabilization and reintegration of social systems. By recognizing that in the high-technology multinational capitalism that characterizes late-modern society all social and cultural forms are potentially interrelated to all others, globalization theory allows for the full interplay of all institutional sectors, including religion, within the explanatory structure of social action. Reaching back, then, into the early American sociology of W. I. Thomas, which Parsons himself intimated in an essay in his 1977 *Social Systems and the Evolution of Action Theory* (p. 48), is the basis of Parson's own "pattern variables" approach within social theory; globalization reinvigorates the study of religion as a category of human action precisely because of its effects within the global system—religion is real because it is real in its effects. As a macro form of Thomas's situationalism, globalization theory achieves what Durkheim attempted to do in removing truth questions from the study of social phenomena (including religion), but could not accomplish using a functionalist definition of social institutions.

Sociology of religion

Because of the intimate relationship between the founding of sociology and its concern with investigating questions of religion, the sociology of religion was among the earliest of the field's subdisciplines, yet, in the United States especially, was among the last to be institutionalized formally in the sectional substructure of the ASA—though it is now among the largest. In most respects, the course of development of the sociology of religion reflects issues and strategies of the larger discipline on the one hand, and general social issues on the other. Especially after the 1950s, leadership from general sociology permeated the sociology of religion and vice versa. For example, J. Milton Yinger wrote crucial texts for the field in the 1960s and 1970s, and was subsequently elected president of the ASA. Similarly, Talcott Parsons was among the founders and one of the first presidents of the Society for the Scientific Study of Religion (as well as a president of the ASA). In other cases, sociologists of religion were among the first to challenge the diffident scientism of the late 1930s and 1940s. Catholic sociologist Paul Hanly Furfey's critique of Lundberg's *Can Science Save Us?* remains a classic in general theory. And it is in the Catholic sociology movement of the late 1930s that the Association for the Sociology of Religion finds its roots.

The 1980s began to see an important shift in sociology of religion approaches in the United States, characterized by what R. Stephen Warner has termed a "new paradigm." The new paradigm particularly shifted away from the secularization model that had dominated sociology from its earliest days and came to emphasize religion as more than either epiphenomenon or residue. In his presidential address to the Southern Sociological Society in 1987, Jeffrey K. Hadden led a direct assault on the core principles of the secularization model. Currently, the new paradigm is most actively pursued through the "supply side" or "rational choice" modeling of a group of scholars whose perspective and conclusions are most fully articulated in Rodney Stark and Roger Finke's *Acts of Faith* (2001), but that rest upon the premise that religious decisions and action patterns are undertaken by people using the same kinds of processes, social or psychological, as characterize all other forms of decision making and action pattern formation—a view that draws heavily upon the work of contemporary Chicago economics professor Gary Becker.

Sociology of knowledge

The sociology of science has usually been treated as a major theme within the sociology of knowledge, which has had close ties with the sociology of religion. Max Weber, for example, tends to use the terms *secularization* and *intellectualization* interchangeably. Secularization refers primarily to a change in epistemological frames; in other words, theological or religious categories no longer provide the major frame of analysis through which everyday life experiences are understood. To the larger debate on the nature of science, Weber also contributed the widely cited essay "Science as a Vocation" ("*Wissenschaft als Beruf,*" perhaps more accurately translated "Scholarship as a Calling," delivered in 1917, published in 1919, and translated into English in 1946). This essay specifically identified detached academic investigation with the Lutheran concept of vocation or calling, ending (as does the Protestant ethic series) with a biblical quote and a prophetic call.

Weber also indirectly influenced the sociology of science through the work of Robert K. Merton, whose Ph.D. thesis, published as *Science, Technology, and Society in Seventeenth-Century England* (1938) used the style of Weber's Protestant ethic thesis to argue for a relationship between Protestantism and the rise of modern science (now known as the *Merton thesis*). Other major contributions within the sociology of knowledge include Karl Mannheim's *Ideology and Utopia* (1936) and Antonio Gramsci's *Prison Notebooks* (written between 1926 and 1937), which is particularly important for Gramsci's treatment of hegemony. Although not strictly sociology, Thomas Kuhn's *Structure of Scientific Revolutions* (1962) must be considered a crucial work for any subsequent sociology of knowledge. In addition to these theoretical contributions, there has also been an enormous volume of empirical work on the demographic, educational, sociocultural, and other background characteristics of people who become scientists, and to a lesser extent to the processes by which scientific communication takes place.

See also LIBERATION THEOLOGY

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WILLIAM H. SWATOS, JR.

SOCIOLOGY OF KNOWLEDGE

See SOCIOLOGY

SOCIOLOGY OF RELIGION

See SOCIOLOGY

SOUL

In English, the term *soul* can refer to a metaphysical entity or to the state of one's character. A philosopher may disdain the first and applaud the second. This entry focuses on the soul as an entity but concludes with noting why work on the soul is often centered on values.

Evolution of the idea

In ancient Greek philosophy the soul was thought of as a principle of life; the soul is what gives a person life as a human being. For Aristotle (384–322 B.C.E.) the soul (Greek, *psyche*) was identified as the form of the body. Aristotle delimited a host of different kinds of souls befitting nonhuman animal and plant life. In plants, for example, the soul was thought to be comprised of the plant's nutritive and reproductive powers. The human soul shares many of the powers of other living things but has distinctive intellectual powers as well. Aristotle's teacher, Plato (428–348 B.C.E.) thought of the human soul as an immaterial concrete subject capable of preexisting the body and living on after the body's destruction. In the important work *De Anima* (On the soul), Aristotle hints at an incorporeal, immaterial aspect to the human soul, but falls short of Plato's more enthusiastic delineation of the soul as independent of the body.

The medieval period favored Plato over Aristotle on the soul, until the Italian philosopher and theologian Thomas Aquinas (1225–1274) appropriated and rethought Aristotle's philosophy of nature in a Christian context. While Aquinas more firmly identified the embodiment of the soul in concrete, material terms, he retained belief in an individual's afterlife and did not embrace a thorough materialism.

The early modern era was profoundly ambivalent about the soul. Modern science was deeply suspicious of Aristotle, and the success of mechanical explanations of the material world were not especially hospitable to the soul and its principles of life. The French philosopher and mathematician René Descartes (1596–1650) demarcated the mind as distinct from the body, but increasingly a form of materialism or naturalism gained ground. Unease about the soul as a distinguishable entity was also fueled by some theologians during the Reformation. Some reformers did not believe the Hebrew Bible welcomed Platonism. In the creation story God makes human beings out of the dust of the ground, into which God breathes the breath of life (Gen. 2:7).

Challenges

The wholesale identification of the soul and the body met with obstacles, however. From the vantage point of modern science, matter (and eventually matter and energy) is not intentional; fundamental physical causal processes do not involve beliefs and desires. If complete and adequate explanations of the cosmos do not involve beliefs and desires, how is one to account for, let alone describe, everyday human activities? Very basic reasoning (*1 + 1 = 2*) seems to be based on beliefs and reasons (because I grasp *1 + 1,* and I grasp that *2* is *1 + 1,* I see that the mathematical relationship is necessary). Mechanistic science seems to write off such psychological accounts of our reasoning. This causes an especially difficult challenge with a mechanistic philosophy, for such a philosophy is customarily introduced as a theory that ought to be accepted based on some plausible beliefs about the evidence. But if the theory is correct, then beliefs play no essential role in explaining states of the world. In other words, mechanical, reductive materialism faces the danger of undermining the common sense understanding of humans as rational agents.

Materialists have developed different replies. The most dramatic, as represented by contemporary cognitive scientists and philosophers Stephen Stich, Paul Churchland, and Patricia Churchland, has been to deny that there are any such things as beliefs and desires. Other materialists have denied that psychological explanations are truly explanations in the same category as a scientific explanations. Some consider these two options desperate, for the first risks self-refutation (Stich *believes* that there are no beliefs) or refutation from common sense, while the second recommends a radical dualism more severe than Descartes's. The alternative, deemed by many to be more promising, is to develop some kind of nonreductive materialism, a theory that recognizes the beliefs, desires, and other powers that used to be associated with the soul, and yet views these beliefs as either identical to, constituted by, or emergent upon physical processes. As of the early 2000s, there is no universally accepted version of nonreductive materialism. Perhaps largely because of this lack of consensus on a problem-free form of materialism, there are some prominent philosophers who defend a form of dualism in which the soul is a distinctive, nonphysical entity.

Arguments over the metaphysics of the soul and arguments over values are closely related. If the whole scope of powers associated with the soul (beliefs, desires) does not exist or has no role to play in a mature explanation of the cosmos, then the values that appear to permeate and define human lives seem to be in jeopardy. It was his perception of this plight that led Stich to revise his radical skepticism about beliefs and desires. The moral implications of eliminating beliefs also led Paul Churchland to try to secure morality within his reductive science; he took on this project under a book title that explicitly refers to the soul: *The Engine of Reason, the Seat of the Soul* (1995).

Some contemporary theologians are highly motivated to see the soul in material terms. Your soul is your material body, functioning physically, psychologically, and spiritually. A dualist view of the soul is sometimes described as more Platonic than Christian. The effort to see human embodiment in integrated terms is easily appreciated, but it is difficult to avoid the dualist implications of the Bible and Christian tradition. If the soul can survive the death of the body (perhaps to be reembodied at the Resurrection), then it appears that the soul and body are not identical.

As in the Christian tradition, Jewish and Islamic philosophers have shifted between material accounts of the soul in the spirit of Aristotlean and Platonic mind-body dualism. Hinduism, Buddhism, and other religions that allow for reincarnation (a rebirth of the soul in distinct material embodiments) explicitly teach or implicitly assume a distinction between body and soul.

While Judaism, Christianity, and Islam have traditionally seen the soul as a substantive individual, enduring over time, Hindu and Buddhist literature have cast the individuality of the soul in more conditional terms. In Advaita Hinduism, different human souls are identical with the singular Divine Being. In the Buddhist tradition, the soul is a composite of perception, intelligence, form, feeling, and volition.

Popular culture in North America since the mid-1980s has seen a great revival of talk about the soul. Popularized forms of Renaissance Platonism have become fashionable. There is also some effort by philosophers to rekindle language about the soul in which having a soul is understood to involve depth of character or a meaningful presence or availability. People may be said to have a soul when they have deep convictions and integrity. The result is that there is more than one way to lose one's soul, either through a radical form of materialism, or through ethical failure, or a break down of integrity, or the refusal to lead an examined life.

See also ARISTOTLE; CONSCIOUSNESS STUDIES; DESCARTES, RENÉ; DUALISM; HUMAN NATURE, RELIGIOUS AND PHILOSOPHICAL ASPECTS; IMAGO DEI; MATERIALISM, PLATO; SPIRIT; THOMAS AQUINAS; VALUE

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CHARLES TALIAFERRO

SPACE

See SPACE AND TIME

SPACE AND TIME

Archeological excavations of ancient temples and tombs have shown that solar seasonal movements were known in neolithic times. Such knowledge depends on a recognition of former events as being in the past and an expectation of events to come as being in the future and, therefore, presupposes awareness of time. Prehistoric peoples must also have appreciated time sequence in the rhythm of the seasons, in plant growth and decay, and in the cycle of birth, life, and death. These cycles of heavenly and earthly events would have suggested that time itself perpetually recurred; to prehistoric peoples, a sense of temporal rhythm was more important than temporal sequence.

Time and religions

It has been suggested that religion originated from human awareness of the inevitable cycle of events. Rites and sacrifices were performed on specific occasions and these were often associated with particular phases of the moon or solar solstices. Other heavenly bodies, as well as the sun and moon, were often regarded as gods. The gods had superhuman powers, but they were thought to have desires and emotions analogous to those of humans, so that they were amenable to entreaty and flattery through propitiation ceremonies. Those who conducted these ceremonies were accorded high status in society: They were priests and often priest-kings. Priests observed the rhythms and movements of heavenly bodies and could predict their positions in the heavens. Babylonian priests, who could predict eclipses of both the sun and the moon, kept continuous records by the first millennium B.C.E.

A theory of time. For ancient civilizations, astronomical knowledge was practical rather than theoretical. The ancient Greeks were the first to develop a more abstract concept of time and its relation to space. Plato (c. 427–347 B.C.E.) and Aristotle (348–322 B.C.E.) had the most profound influence on later Western religious thought. Plato held that the creation of the cosmos was the work of a divine craftsman, the demiurge. The demiurge was not to be conceived as a god in the sense of a powerful spirit, but to be regarded as a principle of reason, who imposed order on the formless and chaotic raw materials of the world. Plato's ideal cosmos was a nonmaterial mathematical model that was immobile, immaterial, eternal, and timeless. But the created material universe was subject to change, a change manifested in the revolutions of the heavenly bodies that Plato identified as time. Therefore, at the creation, the demiurge had produced time as well as space.

Both Plato and Aristotle were influenced by cyclical theories and thought that the circle was a perfect figure because it had no end; it was a symbol of eternity and of a changeless immutable reality. Circular motion, apparent in the revolutions of the heavenly bodies, also displayed this perfection and need have no end. By contrast, motion in a straight line could not continue indefinitely unless the line were of infinite length, and Aristotle did not believe that there could be such a line. Whereas the cyclical theory of events in time ended with Christianity, the almost mystical view of the circle and of perfect, potentially eternal, circular motion permeated and strongly influenced philosophical and religious thought until the seventeenth century.

The Christian concept of time. Plato's postulate of an original chaos from which the demiurge created space and time is unique because he took the material universe to be but a pale reflection of an immaterial, eternal, and changeless reality. The idea of a universe formed from chaos, however, is a feature of many creation myths. It is echoed in Genesis: "In the beginning God created the heaven and the Earth. And the Earth was without form, and void" (Gen. 1:1–2).

The early Christian saint Augustine of Hippo (354–430 C.E.) agreed with Plato that there could be no time without a created universe and that people were aware of time as the sequence of events in the created world. "I know that if nothing passed, there would be no past time; if nothing were going to happen there would be no future time; and if nothing were, there would be no present time" (p. 261). God was the creator of time, though God was outside time. Addressing God, Augustine wrote "although you are before time, it is not in time that you precede it. If this were so you would not be before all time. It is in eternity, which is supreme over time because it is a never-ending present, that you are at once before all past time and after all future time. For what is now the future, once it comes will become the past, whereas you are unchanging, your years can never fail" (p. 263). But Augustine disagreed with Plato's identification of time with the motions of the heavenly bodies. He argued, as had Aristotle, that time measures motion and therefore had to be distinguished from motion. Other Christian philosophers also disagreed with earlier views about the cyclical nature of time. For Christians the crucifixion was a unique event, and time had to be thought of as a unidirectional linear progression from the past, through the present, and on to the future. Though God was aware of past, present, and future in eternity, humans could only proceed forward in time.

Aristotle and the Christian cosmology. After the rediscovery of Aristotle's writings and their evaluation by the Christian saint Thomas Aquinas (1224–1274), Aristotle's cosmology became part of Christian doctrine and also played a major part in philosophical and scientific thought. Aristotle's cosmos was a closed and complicated system of transparent crystalline spheres revolving round the central immobile Earth. In all there were fifty-five such spheres. The moon, the sun, and each of the five planets were embedded in a separate sphere and each was carried round the Earth as its particular sphere rotated in its circular orbit. The fixed stars were all embedded, rather like lights in a ceiling, in an eighth sphere beyond these and beyond that penultimate sphere was the outermost sphere, the sphere of the unmoved mover. Circular motion was perfect and eternal and, for Aristotle, it was the natural motion of the heavens. Aristotle's account was developed further by Claudius Ptolemy (90–168 C.E.), who constructed a table, the *Almagest,* which provided a basis for predicting the positions of the planets in the sky. It was used in navigation, to foretell eclipses, and to calculate the dates of the equinoxes and the date of Easter.

For medieval Christians, Aristotle's cosmology had a religious significance that went far beyond its role in calculating the date of Easter. They regarded the system of spheres as a heavenly hierarchy. Aristotle's ninth sphere, the sphere of the unmoved mover was, for them, the sphere of God in glory. As well as being incorporated into Christian doctrine, the Aristotelian cosmos played an important role in medieval and renaissance literature. In the Paradise of his *Divine Comedy,* the Italian poet Dante (1265–1321) described his ascension outward to higher and higher spheres. For though they were all heavenly, the higher (outer) spheres were considered nearer perfection and the abode of God. This cosmos was closed and finite; there might be disturbances and disarray on Earth but above the sphere of the moon the heavens were an ordered hierarchy showing eternal, regular unchanging circular motion, and creating heavenly harmony: the music of the spheres. More than two centuries after Dante, William Shakespeare described this music in *The Merchant of Venice:*

> Look how the floor of heaven
> Is thick inlaid with patines of bright gold;
> There's not the smallest orb which thou behold'st
> But in his motion like an angel sings,
> Still quiring to the young-eyed cherubims;
> Such harmony is in immortal souls;
> But whilst this muddy vesture of decay
> Doth grossly close it in, we cannot hear it.
> (5.1)

A new cosmology

By the early sixteenth century, navigators voyaging to America and around Southern Africa to India and the Spice Islands found the *Almagest* inadequate; it was also proving unsatisfactory in fixing the date of Easter. Nicolaus Copernicus (1473–1543) was one of several distinguished mathematician astronomers asked to revise and improve on Ptolemy's work. In 1543, the year of his death, Copernicus published his new cosmology placing an immobile sun at the center of the universe and displacing the Earth, which now orbited the sun along with the planets. Copernicus did not think his theory was revolutionary. He regarded it as a modification of the Aristotelian and Ptolemaic cosmos. Copernicus's universe still consisted of concentric crystalline spheres and was closed and finite. However, as a physical account it was incompatible with contemporary (Aristotelian) physics, and it also seemed to flout common sense. In addition there were grave theological objections. Aristotle's cosmology had become part of religious dogma and could not be rejected without firm evidence. Moreover in the early seventeenth century there was an alternative cosmology, that of the Danish astronomer Tycho Brahe (1546–1601), that retained a central immobile Earth and accounted for new observations equally well.

The cosmos of classical physics. In 1543, the crystalline spheres had seemed essential in order to carry the heavenly bodies and to keep them in their orbits. In proposing a Copernican-type cosmos (with a central sun but with no spheres) Galileo Galilei (1564–1642) had to explain how those spheres could be dispensed with. He asserted that all bodies had a natural (inertial) circular motion bestowed by God that would continue indefinitely. This was in accord with the universal belief in the perfection of the circle and of circular motion, a belief that had to be abandoned after Johannes Kepler (1571–1630) showed that the planets revolved in elliptical orbits. But the important change in the cosmology was that the universe, and therefore space, was no longer closed and finite. Copernicus himself had postulated a much larger universe but, for him, it was still closed. After Galileo the universe was seen as potentially infinite. Moreover, since there was no sphere of the moon separating the Earth from the heavenly bodies, the same physical laws that were beginning to be established on Earth also ruled in the heavens. The French philosopher and mathematician René Descartes (1596–1650) was the first to call them the laws of nature. Later he formulated the principle of inertial motion in a straight line. Descartes justified the principle partly by appeal to direct human experience of motion but also by appeal to religious belief. He affirmed that God must be the ultimate cause of all motion and that the amount of motion in the universe must remain constant, an implicit reference to God's perfection and consequent immutability.

Absolute space. Isaac Newton (1642–1737), who developed what is known as classical physics, took the principle of inertial motion in a straight line and, using his laws of force and of gravitational attraction, he was able to confirm Kepler's theory of elliptical orbits. More importantly, Newton established the classical concepts of absolute space and time and distinguished these from relative space and relative time.

If one assumes a homogeneous space extending indefinitely in all directions, then the position of a lone object can not be specified because position has to be related to something, for example another object. Likewise the concept of change of position can have no significance for a lone object. If one assumes just two objects, then if their relative positions change can it be said that only one object moves? If so, which one? Or do both of them move? The answer depends entirely on what one decides to adopt as a point of reference. In everyday experience there are an indefinitely large number of objects in space, and people take reference points that suit their purposes. But is there an absolute reference point? Can space itself provide a reference so that in principle even the position of a lone object could be established? Newton conceived of space itself as having an absolute position, so that any portion of space (as opposed to any body in space) was fixed. For him, space was *sensorium-Dei* (a sense organ of God) and was a manifestation of God. Thus space was eternal and changeless and, therefore, there were absolute, as opposed to relative, positions in space. But only God could know these; Newton appreciated that human beings could not distinguish the parts of space and so had to be content with the relative positions of objects in space.

Absolute time. There is an analogous problem in relation to the measure of time. If nothing whatever were to change, not only would one be unable to measure time, one would not be aware of time passing; time would stand still. Galileo is said, wrongly as it happens, to have used his pulse to time the swings of the pendulum in the cathedral at Pisa. This would not have been an accurate measure because pulses are not completely regular. But how is this known? By comparing pulse rates with a more regular sequence. The most regular sequence is shown to be the most regular because it consistently correlates all other time intervals: This is the only way regularity can be tested. Like Augustine's concept, the mathematical/scientific concept of time in classical physics was that of a steady stream in which "the present," the flow of events, moved forward at a constant rate. Without events and therefore without any change, people could not be aware of time, it would have no empirical significance.

Is it then legitimate to assume an absolute and perfectly regular flow of time? Newton took the existence of absolute time as a fundamental metaphysical postulate: "Absolute time and mathematical time, of itself and from its own nature, flows equably without relation to anything external" (Koyré, p. 7). Newton appreciated that absolute time had to be distinguished from the time that could be measured; he called the latter "relative time," "apparent time" or "common time," and he realized that there was no way to know how close "sensible measures" were to measuring the absolute flow of time. He based his metaphysical assumption on appeal to God. Like absolute space, absolute time was a manifestation of God.

Relativity and the geometry of space

During the fourth century B.C.E., the Greek mathematician Euclid elucidated the nature of space. His geometry consisted of a system of theorems logically deduced from five axioms. The axioms were held to be self-evident and so constituted a set of indubitable premises. Euclidean geometry specified the properties of Euclidean space and these properties were assumed to be logically certain. This was the space of the Greeks, medieval space, and the space of classical physics. During the nineteenth century two mathematicians, Georg Friedrich Bernhard Riemann (1826–1866) and Hermann Minkowski (1864–1909), suggested two different geometries for two theoretical spaces that could be devised by changing Euclid's fifth axiom. That axiom is: Through a point not on a given line there can be only one line that will not cross the given line. Riemann, and later Minkowski, offered alternatives: There is no line that will not cross the given line, or there are an indefinitely large number of lines that will not cross the given line. The changed axioms defined two different non-Euclidean spaces, but when first formulated they were regarded as nothing more than mathematical speculations that did not apply to the real world.

In the nineteenth century no one questioned the assumption that space was Euclidean space and that measurements of space and measurements of time were independent of the motion of the observer. Parallel lines did not meet, distances remained constant, and clocks ran at a constant rate. It was these assumptions that were to be undermined by Albert Einstein (1879–1955). Einstein's new physics arose from his study of problems relating to the transmission of light and other electromagnetic vibrations. To solve the problems, Einstein had to postulate that the velocity of light was constant in all so-called inertial frames of reference so that it would remain the same for two or more observers moving at different velocities relative to each other. Such a postulate would have been nonsensical in classical physics and entailed a fundamental reassessment of assumptions about time, space, and motion.

In his reassessment. Einstein did not jettison common sense; rather he invited his colleagues to consider fundamental concepts on the basis of a common-sense analysis of the significance of familiar and ordinary terms. Einstein argued that the crucial element in a person's notion of time was that of simultaneity because any judgment made of time and the time of an event must be a judgment of the simultaneity of that event with another event. For example, to say that a train arrives at seven o'clock is equivalent to saying that it arrives when the small clock hand points to seven; the two events are claimed to be simultaneous. Einstein was the first to point out that there had to be a finite time for the light conveying the information about the position of the clock hand to reach a site a finite distance from the clock, and that clocks must be calibrated to allow for this. Calibration is possible if the clock and the observer are in the same frame of reference. But because light travels at the same velocity for observers in different frames of reference (e.g., traveling in cars toward the station) calibration is not possible. It follows that there can be no agreement about simultaneity and therefore no agreement about the time of the train. Of course because light travels millions of times faster than any car, the disagreement would not be noticed, but a discrepancy can be detected in careful experiments. Einstein was able to show that as the velocity of a frame of reference increased relative to an observer outside the frame, the bodies within the moving frame would appear to contract. Observers in the moving system would see no change and to them the objects in the "stationary" frame of reference would seem to shrivel. Thus time and space could not be regarded as absolutes: They were observation-frame-dependent. A further consequence of Einstein's new physics was that space and time themselves were distorted by mass and were to be described by the geometry of Riemann or Minkowski rather than that of Euclid.

Minkowski had been Einstein's teacher and he proposed a way to establish independence of the frame of reference. In a lecture "Space and Time," given in 1908, Minkowski suggested that events should be identified and described by their positions in space-time. This would allow objective measurements but it would entail making space and time interdependent because the "time axis" would be as necessary for a description as the three space axes. Unfortunately, people find it very difficult to envisage events in four (as opposed to three) dimensions, and Minkowski's suggestion removes physical accounts of objects and events from common-sense intuitions. Space-time is a concept that can be regarded as providing a different metaphysical framework that could replace the two Newtonian concepts of absolute space and absolute time. However, within any given frame of reference, one can use classical physics and it can apply in a different frame with velocities that are small compared to the velocity of light. This is the case in most situations, and why classical physical laws still hold. But these laws are approximation, and one must concede that classical (and indeed intuitive) concepts of time and space are flawed.

Metaphysics and religious belief

Although this account has been primarily concerned with Christianity, the nature of the religious beliefs of Copernicus, Galileo, Kepler, Descartes, Newton, and many others was grounded in a mystical acceptance of a higher power rather than in Christian doctrine. Underlying their heterodox and even heretical opinions was the faith that human reason was a gift of God and it was adequate to the task of explaining events in the world.

By the end of the twentieth century, science rarely made direct appeal to religious faith. The theoretical physicist Stephen Hawking (b. 1942) allows for the need to appeal to some power transcending human capacities to account for creation. In a chapter significantly called "The Origin and Fate of the Universe," in his popular book *A Brief History of Time* (1988), Hawking reveals a Cartesian concept of laws of nature, and though, unlike Descartes, he does not postulate that they are divine decrees, he does entertain the notion. Hawking argues that events cannot be random and, whether they be divine or no, there must be laws of nature. He appears reasonably confident that human beings will arrive at a complete explanation (a unified theory) "within the lifetime of some of us" (p. 156). But his confidence may be misplaced, not only because evidence from the past gives greater grounds for pessimism than Hawking is prepared to acknowledge, but because it remains an open question as to whether the laws of nature are not *human* constructions. What Hawking does clearly reveal is the necessity for metaphysical and possibly religious beliefs. His expositions show that the basic metaphysical assumptions of Aristotle, the medieval scholars, the founders of classical physics, and the founders of modern physics are still in play. The assumption is that there is an objective order and that humanity is capable of discovering that order.

See also ARISTOTLE; AUGUSTINE; EINSTEIN, ALBERT; GALILEO GALILEI; GEOMETRY: PHILOSOPHICAL ASPECTS; GEOMETRY, MODERN: THEOLOGICAL ASPECTS; NEWTON, ISAAC; PLATO; RELATIVITY, GENERAL THEORY OF; THOMAS AQUINAS

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JENNIFER L. TRUSTED

SPACE-TIME

See SPACE AND TIME

SPECIAL DIVINE ACTION

Special, or particular, divine action stands in contrast to ordinary, or general, divine action. God can be said to act generally through the regular structures of the world, which God creates and sustains. In addition, God may perform particular actions to achieve specific divine purposes in history, as in the self-revealing and redemptive acts depicted in biblical narratives. Modern theologians have found that the idea of special divine action presents difficult interpretive challenges, especially in light of scientific descriptions of the world as an integral structure of natural causes, and they have sought ways to identify what makes such events special other than miraculous divine intervention in the world.

See also DIVINE ACTION; PROVIDENCE; SPECIAL PROVIDENCE

THOMAS F. TRACY

SPECIAL PROVIDENCE

Classical forms of Judaism, Christianity, and Islam claim that God guides or intervenes in human history. God's intentions are thereby manifest not just in the general laws of nature but in specific events like Abraham's call to worship God, Christ's life, and the revelation of God's word to Muhammad. Theologians in monotheistic traditions have generally understood God's specific will for empires or individuals as governed by God's will for the good of all creation. From this point of view, God's having a "chosen people" is for the benefit of all. God's special provident action is at the heart of the prophetic tradition in monotheism. It also plays a role in the ancient and contemporary practice of prayer in which one petitions God for some good. Ancient polytheistic religions in Greece and Rome were largely built around divinization (determining the disposition of the gods toward one's petition) and supplications backed by bargains, whereas monotheistic spirituality over the centuries has tended to shun the practice of trying to control God's will out of self-interest.

Three lively philosophical issues arise over special providence: the scope of providence (Is the future predetermined or predestined? Is freedom compatible with providence?); the relation between God's general and special intentions (Can God suspend certain general ethical prohibitions?); and the existence and nature of miracles. Some specific provident acts may be in keeping with, and thus allowed by, the laws of nature, whereas others seem to involve going beyond or against the natural course of events (e.g., a dead man being resurrected).

See also DIVINE ACTION; FREEDOM; MIRACLE; PROVIDENCE; SKYHOOKS; SPECIAL DIVINE ACTION

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CHARLES TALIAFERRO

SPECIAL THEORY OF RELATIVITY

See RELATIVITY, SPECIAL THEORY OF

SPIRIT

Spirit is a complicated, nebulous term extending from the sacred and holy to the depths of the human. It captures human consciousness of meanings and purposes extending beyond individual lives, and directs people to the boundaries of self. Spirit may also refer to the supernatural or immaterial, the divine or sacred, an animating principle, a property of the person, mind or consciousness, the process of emergence or coming into being, an orientation to ultimate mystery, and the ethical or transformative. There is a Christian tradition, from Irenaeus in the second century to Erasmus in the sixteenth, that views the human person as a tripartite complex of spirit, soul, and body, but there is an alternative sense in which these are varying orientations of a unitary person. With reference to the individual, spirit and soul are used almost interchangeably, although spirit tends to be less individuated, and the soul more tied to the religious.

Theological development

Theological developments begin with the ancient understanding of spirit as life. The Hebrews used the word *ruach* to refer to divine breath, and the word *nephesh* to refer to a product of the spirit, translated as "person" or "soul." The Greek term *pneuma,* meaning "breath of life," is translated as "spirit" of life and breath and is distinguishable from the images and ideas of the *psyche,* translated as "soul" or "mind.". This sense of spirit may also include the "new life" of prophetic inspiration, art, poetry, and courage.

The ancient Hebrews understood humans to be unitary persons, which is also consistent with the early Epistles of the New Testament. The medieval Christian philosopher Thomas Aquinas (c. 1225–1274) drew on Aristotle's understanding of form as inseparable from substance, seeing the human spirit inseparable from its corporeality. A disembodied soul may be theologically problematic, both in failing to fulfill the total life of a person and in negating of the body. A deeply immanent view of the relation between spirit and life is also found in modern theologies like that of Pierre Teilhard de Chardin (1881–1955), Karl Rahner (1904–1984), and Wolfhart Pannenberg (b. 1928). On this view, evolution itself is the continuous development of matter towards spirit, nature becoming conscious of itself in human beings, systems open to the future.

The idea of spirit is restricted to *mind* in early Christian syntheses, equivalent to the Latin word *mens* for Augustine of Hippo (354–430 C.E.). He sees the self as transcendent in all of its functions, including memory and understanding, and his emphasis on private experience contributed to the inwardness institutionalized by Christianity. During the seventeenth century, René Descartes argued that mental faculties are largely explainable as bodily activities, except for conscious thought. To account for consciousness, Descartes posits a nonmaterial dual substance, causally interacting with the brain, knowable only through privileged and incorrigible introspection. Contemporary solutions to the mind-body problem recognize an inescapable dependence on mind upon brain, but have not yet explained subjective experience.

A tension remains between a view of spirit as internal or as external to the human mind. Pannenberg warns that while the identification of spirit with mind may be a human projection, its Christian opposition often results in irrational subjectivism (p. 127). Spirit as the principle of life may be generative of mind, more than an individual's brain function, but a set of interiorized relationships. Even a scientific understanding of mind may require more than individual neurobiology, but it is not clear whether spirit requires a further step, since human invention and divine inspiration are not mutually exclusive.

Human spirit has also been equated with self-transcendence, intimately tied to human freedom and development. The theologies of Teilhard de Chardin and Paul Tillich (1886–1905) treat spirit as a dimension of life that takes one's biological, individual self-awareness into the personal and communal, with ecstatic acts of self-transcendence overcoming existential anxiety. According to Rahner, human minds enable the abstraction by which people move beyond themselves to a horizon of meaning. If spirit is about the meanings that transcend human finitude, it can encourage an obliteration of a bounded and autonomous self. The theological idea of *kenosis* captures this idea of emptying the self into a larger vessel. The spirit is then constituted by stepping beyond the boundaries of self, in relating to others and, as Rahner writes, to the "unutterable mystery of life we call God" (Grenz and Olson, p. 240).

Science and religion

In the dialogue between science and religion, spirit is a bridging concept between the ultimate metaphysical concerns of religion and their embodiment within human experience. The sense of spirit as an immanent creative force finds expression in process theology's use of developments in physics to understand even matter as including an experiential interior. This sense is also seen in the use of chaos theory, complexity theory, and autopoesis to understand the work of spirit. Ian Barbour sees spirit in the emergent novelties of evolution, including unique activities at higher levels of organic complexity.

Most uses of spirit in the science-religion dialogue have been in making sense of the evolutionary biology of human mental and moral lives, including both an opposition to theological dualism and an understanding that a reductive materialism would explain away much of what is important about human life. The beacon for theological anthropology is the view that spirit, soul, person, and mind are emergent properties of evolved human biology. Under this view, persons are psychosomatically unitary organisms, characterized by an inner life of extreme complexity, unpredictability, and novelty in which the evolution and development of complex nervous systems bring autonomy, identity, and will into being. The human spirit is a contingent product of a hierarchy of biological functions on which personal existence depends, and which gives rise to capacities like morality and religious experience. In theologies of nature like those of Ian Barbour, Arthur Peacocke, and Philip Hefner, human personal and social lives are intimately related to the rest of natural creation by virtue of evolutionary emergence and novelty, mind and spirit. Religious neuroscientists, such as Donald Mackay, Malcolm Jeeves, and Fraser Watts, also emphasize a complementarity or compatibilism between neuroscience and theology. While higher-order properties physically depend on their components, relationships between the emergent unit and its elements is neither identical with nor derivable from them. Philosophically oriented thinkers, such as Nancey Murphy and Philip Clayton, describe spiritual and mental events as "supervenient" over neurophysiological ones, and as both multiply realizable and multiply constitutable. Warren Brown and John Teske suggest further that human spirituality is neuropsychologically constituted only in the context of personal relationships, and in the shaping of human brains by cultural forces.

A range of naturalistic theories of religious experiences ties them to patterns of emotional attachment and to neural structures as in Eugene d'Aquili's life-long program, synthesized in *The Mystical Mind* (1999). Disciplines like prayer and meditation have documentable physical effects, and a whole literature exists on the psychological benefits of spirituality. A tradition of research in the psychology of spiritual development, of which James Fowler's *Stages of Faith* (1981) is the best known, also connects the interdependent self of mature ego-development to the breakdown of self/other boundaries sought by spiritual and ethical traditions. At higher levels of development, spirit is really not about the individual, nor is it otherworldly, but still strongly opposes a materialistic ethic.

See also ARISTOTLE; AUGUSTINE; DESCARTES, RENÉ; DUALISM; FREEDOM; HOLY SPIRIT; HUMAN NATURE, RELIGIOUS AND PHILOSOPHICAL ASPECTS; KENOSIS; MATERIALISM; NEUROSCIENCES; PHYSICALISM, REDUCTIVE AND NONREDUCTIVE; PNEUMATOLOGY; PROCESS THOUGHT; SELF; SELF-TRANSCENDENCE; SOUL; SPIRITUALITY; SUPERNATURALISM; TEILHARD DE CHARDIN, PIERRE; THOMAS AQUINAS; WHITEHEAD, ALFRED NORTH

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JOHN A. TESKE

SPIRITUALITY

In the contemporary context, the term *spirituality* has a vast spectrum of meanings. It can refer to an interior journey, to the practice of prayer and meditation, to faithful and righteous living, or to a general commitment to authenticity and self-awareness. The term originated in the Roman Catholic tradition, but has been embraced by many Protestants as well as Jews, Buddhists, Muslims, Hindus, Taoists, Confucianists and even secular persons. Indeed, many today claim spirituality while renouncing institutional religion.

Spiritual practice

Prayer, ritual, and meditation remain central spiritual practices across religious traditions. Yet, the notion of what constitutes a spiritual practice also is expanding. Spirituality does not mean simply the interior life or religious discipline. Rather, spirituality relates also to social action, ethical choice, family commitments, friendship, work, and politics. Thus, both private and public practices form the human being and can be spaces for spiritual expression and growth. Indeed, some are defining spirituality so broadly as to include a wide range of contemporary secular practices. One may point, for example, to the 1996 book *Spirituality and the Secular Quest* edited by Peter Van Ness, which includes chapters on scientific inquiry, sports, psychotherapy, the arts, ecological activism, and holistic health practices. These expansive understandings of spirituality rightly avoid a narrow focus on interiority and counter an otherworldly or individualistic notion of the spiritual life. Yet, as the words *spiritual* and *spirituality* are applied to a wider range of beliefs and practices, their meanings can become diffuse and vague. This situation calls for careful theological and philosophical exploration of the wide-ranging meanings of the terms in specific cultural and religious contexts.

Contemporary persons embrace spirituality because they seek to live more deeply, to connect with the ultimate, to find meaning in ordinary activities and the experiences of fragmentation, moral challenge, grief, illness, and death. Spirituality can be understood as the universal human desire for self-transcendence, as Christian theologian Sandra Schneiders writes in her 1986 article "Theology and Spirituality: Strangers, Rivals, or Partners?" (p. 266). Such a broad, anthropological perspective attempts to provide a general, inclusive understanding of spirituality that can speak to the wide range of practices and worldviews that fall under the heading of *spirituality.* Such definitions of spirituality enable dialogue and even shared practice in pluralistic settings. Thus, for example, the editors of Crossroad Publishing's World Spirituality series arrived at a shared definition applicable to studies in everything from Native American to Jewish to Buddhist to Confucian spirituality. As stated in Ewert Cousins's preface to each volume, authors would focus on the discovery of "the deepest center of the person . . . [where] the person is open to the transcendent dimension; it is here that the person experiences ultimate reality."

Yet, every definition of spirituality reflects a theological perspective and an historical and cultural context. Thus, more theologically explicit and context specific definitions of spirituality are important. Christian spirituality, for example, could be understood as life in the Spirit of God, a path in which one walks as a disciple of Jesus Christ—revealed by the Creator in history—within the community of the church. Buddhist spirituality has been defined in terms of "cultivation" that leads, according to the Buddhist monk Rahula Walpola, to "the attainment of the highest wisdom which sees the nature of things as they are, and realizes the Ultimate Truth, Nirvana" (Yoshinori, p. xiii). One then would explore how the particular contours of these paths take shape differently in diverse cultures and historical periods. For indeed, history and culture shape how humans understands themselves, the nature of the ultimate, and the relationship between the two. For example, medieval notions of a hierarchy of spiritual paths—with the celibate path being higher and more perfect than the lay path—reflected a hierarchical social order as well as a specific theological tradition. Scientific discoveries challenge traditional understandings of prayer and divine agency. Contemporary spirituality strongly reflects the "turn to the subject" and the powerful influence of therapeutic perspectives.

Spirituality and the practice of science. As understandings of spirituality widen, science can be understood as a spiritual practice—an attentive search for understanding of the intricate and extraordinarily complex world around us (or within us). The practice of science merges the power of reason with the humility and curiosity needed to see beyond the self. Whether tracing the working of the neuron or investigating the organization of the universe, scientific inquiry requires discipline, awareness, and creativity.

Spirituality and health. While Western medicine has become highly secularized, there remains a strong academic and popular interest in exploring connections between spirituality and health. This interest takes two forms. One is the general insistence on the relatedness of body, mind, and spirit. For example, Robert C. Fuller notes that the holistic healing movement seeks a natural renewal of physical well-being through an individual's own psychological and spiritual energies (Van Ness, pp. 227-250). These practices need not claim a metaphysical reality responsible for healing. The second kind of interest presupposes a higher being—a life-giving Creator—that sustains or restores bodily health. Studies have found a correlation between prayer and religious beliefs and effective coping, resilience, and healing (e.g., Oxnam et al.; Levin and Schiller). The question is whether spiritual practices simply benefit one's mental outlook and physical condition or whether they effectively draw supernatural power upon the body.

Spirituality and faith healing. Diverse religious traditions long have believed that a divine being can cure illness. Faith in God enables human beings to convey God's healing touch or combat evil forces. Many Christians, for example, believe that spiritual practices such as prayer, exorcism, and anointing can restore health as Christ is chronicled as doing in the Gospels (e.g., Mark 6:13).

Christian Scientists make faith healing the center of their belief system and maintain as a principal tenet that true understanding alleviates disease. Adherents to Buddhism, Shintoism, and Daoism often wear amulets to ward off illness. In different ways, various spiritual practices orient one toward the divine healing power.

Study of spirituality

The study of spirituality must be an interdisciplinary enterprise. It draws on multiple fields in order to understand the human quest for the ultimate and the practices that open one to truth and wisdom. The study of spirituality incorporates theology, history, anthropology, psychology, neurophysiology, medicine, literary studies, and the arts. In the early centuries of Christianity, spirituality and theology were integrated and inseparable. One could not seek knowledge of God without praying and meditating on the scriptures. With the rise of scholasticism in the Middle Ages, theology in Western Christianity gradually became understood as a conceptual science distinct from ascetical or mystical life. This was an unfortunate separation of science and spirituality, a separation resisted in Eastern Orthodoxy and one that some contemporary scholars, such as Philip Sheldrake and Mark A. McIntosh, are reconsidering.

Spirituality has also suffered from misunderstandings about the relationship between the spiritual and the material. Within Christianity, for example, the spiritual too often is seen as that which is beyond or even opposed to the physical, the body, and the material world. It is worth reviewing the meanings of the term *spirit* in the Jewish and Christian traditions—a complicated subject, for this term has multiple meanings in different texts. With this caution in mind, one may note that in the Hebrew Bible the term *ruah* refers to the breath or spirit of God, a life-giving force. In the New Testament, *pneuma* (Greek) or *spiritus* (Latin translation) refers often to the Holy Spirit or the animating principle of the human being. To be a spiritual person, then, is to be infused with the life, the breath, of the divine. The Letters of Paul contrast *pneuma* to *sarx* (Greek: flesh). This distinction has been interpreted as pitting the spirit against the flesh. In reality, the texts contrast those things that are "of the Spirit" to those things that are counter to God. To live "in the Spirit" is not necessarily to reject the physical, but to live according to the will of God as revealed in Jesus Christ. Certainly, Christian theology has perpetuated deep ambiguity about the value of the physical. While a dichotomy between the physical and the spiritual persists in numerous religious traditions, contemporary writers in spirituality also promote more holistic notions of spirituality. Widespread interest in such practices as yoga and Tai Chi demonstrate a hunger to integrate spirituality and physicality. Spirituality refers to an authentic and holy life in all its aspects. Thus, spirituality incorporates holy treatment of, or relationship to, the body and the physical world. It also includes a lively curiosity about the material world.

See also MYSTICISM; PRAYER AND MEDITATION

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CLAIRE E. WOLFTEICH

SPIRITUALITY AND FAITH HEALING

Seen from a cross-cultural perspective, diverse traditions of healing, which respond to different conceptions of illness itself, fall under the heading of what may be called faith healing. This entry surveys faith healing activity according to seven categories: (1) intercessory prayer; (2) mind-body research; (3) laying on of hands; (4) complementary and alternative medicine; (5) Asian healing practices; (6) shamanistic practices; and (7) African and other tribal practices. Although these categories by no means represent the entire range of practices that could be construed as faith healing, they do epitomize a spiritual approach to healing. They are also areas in which important scientific and other scholarly research has been conducted.

Western approaches

Evidencing increasing respect for spirituality within the healthcare community, scientific research in the domain of modern Western medicine has examined the impact of spirituality on healing in the areas of intercessory prayer, mind-body connectivity, laying on of hands, and complementary and alternative medicine.

Intercessory prayer. In attempting to determine the impact of faith on health, some researchers have looked to prayer to determine its impact on the health and well being of patients. For example, in 2000, D. A. Matthews and colleagues published a study on the impact of intercessory prayer on patients suffering from rheumatoid arthritis. The study showed that patients receiving in-person prayer "showed significant overall improvement during 1-year follow-up," causing the study's authors to conclude that "in-person intercessory prayer may be a useful adjunct to standard medical care for certain patients with rheumatoid arthritis." In 2001, W. J. Matthews and colleagues published a discussion of the impact of intercessory prayer and other behavioral interventions for kidney dialysis patients.

In another example, noting, "intercessory prayer (praying for others) has been a common response to sickness for millennia," W. S. Harris and colleagues examine whether or not remote (as opposed to nonremote) intercessory prayer reduces "overall adverse events and length of stay" for hospitalized cardiac patients. Employing a controlled, double-blind, parallel-group trial in a private university-associated hospital, Harris and colleagues examined 990 consecutive patients admitted for coronary care. Researchers randomized patients, who received either remote intercessory prayer (the "prayer group") or no prayer (the "usual care group"). Outside intercessors, who did not know and did not meet the patients, prayed for patients in the prayer group daily for four weeks. The patients themselves did not know that people were praying for them. At the conclusion of the study, the researchers reported that, although the two groups did not evidence any differences in the lengths of their coronary care unit and hospital stays, the group that was prayed for displayed lower coronary care unit scores, suggesting "that prayer may be an effective adjunct to standard medical care." Despite this optimistic conclusion, peers have questioned the potential increase in clinical outcome of patients receiving intercessory prayer. For example, R. M. Hamm's article "No Effect of Intercessory Prayer Has Been Proven" (2000) claims that the study described above may have attributed too much importance to results of minimal statistical significance, while another 2000 article by D. R. Hoover and J. B. Margolick in the Archives of Internal Medicine questions the appropriateness of the study's statistical methods in relationship to the type of data collected.

In "The Healing Power of Intercessory Prayer" (2001), O. G. Harding provides an interesting treatment of the more metaphysical implications of efficacious, remote, intercessory prayer. Harding states that "arising from an emerging world view in philosophy, it is argued that the mind can function beyond the individual and is not constrained by time and distance; it is in fact non-local. Prayer is cited as an example of non-local manifestation of consciousness." Harding presents two case studies providing evidence for non-local healing and asks "whether there is no place in medicine for a multiple approach to healing," and, further, if "reported studies of [efficacious] prayer therapies are meaningful, are physicians not using these additional treatments withholding something curative from their patients?" In general, if, despite methodological criticisms of existing research, one emerges convinced that prayer successfully improves health outcomes in some circumstances, one still must answer the question of what mechanisms support healing, both in cases when patients are aware they are being prayed for, but also when they are unaware that others engage in prayers on their behalf. While some may adopt a theological interpretation of such results by claiming that God answers prayers on behalf of the sick and dying, others may prefer to believe that either the patient's own response to the knowledge that they are being prayed for (in the case of nonremote intercessory prayer) or the force of positive, non-localized human intentionality (in the case of remote intercessory prayer) may exert some influence on actual events, such as whether or not a patient recovers from an illness.

Mind/body research. In addition to researching the impact of intercessory prayer, the Western medical community has also examined the impact of spirituality on health in the context of research on the connection between mind and body. Initiatives emanating out of the Mind/Body Medical Institute at Harvard Medical School in Cambridge, Massachusetts, lead research in this area and focus primarily on the positive therapeutic effects of quieting, meditative practice (called "the relaxation response" by Dr. Herbert Benson and his colleagues) on general health outcomes in a range of areas. Benson and his colleagues define the relaxation response "as a series of coordinated physiologic changes elicited when a person engages in a repetitive word, sound or phrase or prayer, and passively disregards intrusive thoughts. Relaxation response practice results in decreased metabolism, heart rate, rate of breathing, and distinctive slower brain waves. These changes are the exact opposite of those induced by the fight or flight response" (Mind/body, 2002). Benson and his colleagues claim that, when combined with exercise, stress management, and proper nutrition, the relaxation response functions as an effective therapeutic intervention for "cardiac disease, many forms of chronic pain, infertility, insomnia, premenstrual syndrome, the symptoms of cancer and HIV/AIDS, anxiety, and mild and moderate depression" -i.e., any condition "caused or made worse by stress" (Mind/body, 2002). By far the most high-profile provider of spirituality and health research and treatment, the Mind/Body Medical Clinic and Beth Israel Deaconess Medical Center in Massachusetts and affiliate sites throughout the United States enjoy over nine thousand patient visits per year. The Mind/Body Medical Institute offers training in the relaxation response to teachers and students, business people, health care professionals, and members of the public.

Laying on of hands. Western medical attention has also focused on the "laying on of hands," which although viewed by some as more of a supplemental, palliative nursing treatment, also serves as a topic for rigorous research. In one interesting study, researchers examined physician attitudes toward the laying on of hands in the context of the AIDS epidemic and concern about HIV infection. The researchers concluded that physicians believed touch facilitated healing and strengthened rapport, though younger physicians, those working in primary care, and those who did not prefer to wear gloves were more likely to express such attitudes.

Complementary and alternative medicine. Although scientific investigation in faith-based healing has increased significantly, M. R. Tonelli and T. C. Callahan ask in their article "Why Alternative Medicine Cannot Be Evidence-Based" (2001) whether the scientific method adequately assesses many "alternative" approaches to healing. They note that "the concept of evidence-based medicine (EBM) has been widely adopted by orthodox Western medicine. Proponents of EBM have argued that complementary and alternative medicine (CAM) modalities ought to be subjected to rigorous, controlled clinical trials in order to assess their efficacy. However, this does not represent a scientific necessity, but rather is a philosophical demand: promoters of EBM seek to establish their particular epistemology as the primary arbiter of all medical knowledge." Tonelli and Callahan believe instead that "methods for obtaining knowledge in a healing art must be coherent with that art's underlying understanding and theory of illness. Thus, the method of EBM and the knowledge gained from population-based studies may not be the best way to assess certain CAM practices, which view illness and healing within the context of a particular individual only." Since many alternative approaches to healing admit the existence of "non-measurable but perceptible aspects of illness and health (e.g., Qi)," controlled clinical trials may not offer appropriate methods of assessment. The authors conclude that "orthodox medicine should consider abandoning demands that CAM become evidence-based, at least as 'evidence' is currently narrowly defined, but insist instead upon a more complete and coherent description and defense of the alternative epistemic methods and tools of these disciplines."

Some studies (e.g., Eisenberg et al, 2001; Parkman, 2002) demonstrate that a growing number of people consider the combination of orthodox treatments and complementary and alternative therapies to be more effective than either kind of treatment alone. Patients with higher anxiety approach faith healers more often, though not to reject more conventional scientific approaches, but as a continuation of them (Conroy et al, 2000). In his article "'Physician, Heal Thyself': How Teaching Holistic Medicine Differs from Teaching CAM" (2001), J. Graham-Pole differentiates CAM ("a system of health care not generally recognized as part of mainstream medical practice") and holistic medicine ("the art and science of healing the whole person-body, mind, and spirit-in relation to that person's community and environment"). Although at least two-thirds of medical schools in the United States offer coursework in CAM, and while an increasing number of courses in the medical humanities focus on spirituality and health, courses on holistic medicine remain rare. According to Graham-Pole, "offering physicians-to-be more coursework in holistic medicine could lay the groundwork for future physicians' adopting and modeling healthy lifestyles."

Non-Western approaches

Moving from Western approaches to non-Western ones, studies on Asian, shamanistic, and African tribal healing practices have contributed to the overall discussion of faith healing. Cross-cultural forms of faith-related healing have also achieved prominent medical investigation, both by Western researchers and by professionals from within particular cultural contexts. For example, V. Griffiths in "Eastern and Western Paradigms" (1999) comments on the holistic nature of Chinese medicine and its attention to observation, subjectivity, and feeling. Chinese medicine revolves around the notion of qi, "an alleged vital force that underlies functioning of body, mind, and spirit" (Raso, 2000) According to a 2002 article by W. Yao and colleagues, "cardiac deficiency of qi (vital energy)" is "one of the main syndromes in terms of TCM (Traditional Chinese Medicine)." Furthermore, based upon a study of forty-four Wistar female rats, B. W. Fang and colleagues contend that "the mixture of reinforcing qi and promoting blood circulation has the function of alleviating pathological changes of liver, reducing the content of liver collagen, improving erythrocytic function of clearing away immune complexes and regulating humoral immune response."

Specialists in Chinese medicine channel qi as part of qigong therapy, which aims "to 'stimulate' and 'balance' the flow of qi . . . through meridians ('energy pathways')." Qigong is a Chinese form of self-healing somewhat similar to some forms of meditative or prayer-based healing. "It involves contemplation, visualization (imagery), assumption of postures, and stylized breathing and body movements" (Raso, 2000). Somewhat similar to qigong, a Japanese form of healing, shinkiko, also relies on interaction with a spiritual realm of energy for healing. Although researchers have not yet studied this form of healing extensively, its popularity is growing in the West in conjunction with the increasingly high profile enjoyed by energy-based healing arts.

Some aspects of faith healing in cross-cultural perspective, such as shamanism and tribal practices, involve belief in spiritual realms accessible by healers on behalf of their patients. Shamanic healing practices often include "sensing and removing 'localized spiritual illness and pain'" in addition to techniques such as soul retrieval and the integration of parts of the soul (Raso, 2000). In the article "Clown Doctors: Shaman Healers of Western Medicine" (1995), L. M. van Blerkom observes similarities between shamanic healing and various palliative treatments in the West, specifically the Big Apple Circus Clown Care Unit, which works with children in New York City hospitals. According to van Blerkom, "there is not only superficial resemblance-weird costumes, music, sleight of hand, puppet/spirit helpers, and ventriloquism-but also similarity in the meanings and functions of their performances. Both clown and shaman violate natural and cultural rules in their performances. Both help patient and family deal with illness. Both use suggestion and manipulation of medical symbols in attempting to alleviate their patients' distress."

As Western medicine continues to gain acceptance in other parts of the world, it increasingly will face the task of integrating itself gracefully with traditional healing systems such that the different traditions can work together in a complementary fashion. For example, in Israel, Bedouin-Arabs (especially women) approach traditional healers before they seek biomedical health care. "The traditional system struck a stronger therapeutic alliance, tended to diagnose more comprehensibly, and was perceived by many patients as being more clinically beneficial." Furthermore, traditional healers can help biomedical practitioners "incorporate the family/community in treatment, and communicate in the patient's cultural idiom" (Al-Krenawi and Graham).

In the context of Africa, traditional tribal healing practices can work together with Western methods effectively, as, for example, in the case of treatment and education for diabetes in South Africa (Peltzer et al). Additionally, V. G. Chipfakacha argues in "STD/HIV/AIDS Knowledge, Beliefs, and Practices of Traditional Healers in Botswana" (1997) that "rapport between traditional healers and scientific medical personnel is essential for an effective and successful HIV/AIDS prevention and control programme" in the context of Africa because approximately seventy percent of African patients see traditional healers. Traditional healers experience increasing risk of contact with HIV/AIDS, which makes it imperative that they receive correct information about the virus and the disease.

See also PRAYER AND MEDITATION; SPIRITUALITY AND HEALTH

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JENSINE ANDRESEN

SPIRITUALITY AND HEALTH

The topic of spirituality and health concerns the ways in which spirituality broadly understood is intertwined with concrete health status, both positive and negative. For example, in both indigenous and world religions, beliefs that demons or other malevolent spirits inhabit one's body may be taken as an explanation for mental or physical illness. Native healers and priests appropriately prescribe exorcisms in such cases, with "appropriateness" determined by the mythopoetic and narrative frameworks of the cultural context. Similarly, some religious communities (Benedictines, for example) view spirituality itself as an indicator of good health, understood as one's degree of meaningful integration with the fabric of the cosmos.

Since about 1980, such traditional portrayals of the relationship between spirituality and health have given way to a burgeoning literature bridging empirical and impressionistic domains that seeks to demonstrate linkages between one's type and level of spiritual and religious involvement on the one hand, and one's health status on the other. A comprehensive survey of this literature reveals many articles on the relationship between spirituality and coping that examine, for example, how spirituality assists in coping with major health challenges (Koenig, et al. 2001), such as cancer (Acklin, Borman), AIDS (Somlai et al.), stress (Joseph), and abuse (Ryan); how spirituality assists in coping with mortality and death (Rutledge et al., Atkinson); and how spirituality and aging relate to one another (Markides et al.). Another interesting category of research focuses on the long-term and therapeutic dimensions of religiosity and spirituality as they relate to mental health and therapy (Fukuyama and Sevig).

One prominent researcher in the field of spirituality and health, Harold G. Koenig, has worked with colleagues to examine religion as a coping strategy (Harold G. Koenig et al 1998) and how cultural diversity impacts care at the end of life (Barbara Koenig 1998). Harold Koenig also explores the relationship between spirituality, health, and aging (Koenig et al 1988), specifically focusing on mental health (Koenig 1994).

Additionally, in conjunction with the twelve-step movement, some researchers have posited that spirituality helps alleviate tendencies toward substance abuse (Pardini et al., Peetet). This last category of research raises interesting possibilities concerning a potential underside to the relationship between spirituality and health, since literature on religious addiction (Arterburn and Felton) may imply that spiritual practices themselves have the potential to activate the same neurocognitive pathways that support addictive behaviors in general.

Investigators also have examined the role of forgiveness, empathy, and altruism in contributing to positive health outcomes (Aderman and Berkowitz). Future research in this area, which will continue to be complemented by research in evolutionary biology on altruism among nonhuman primates and on the evolution of altruism itself, promises to expand the picture of what "health" itself may mean for human beings, for other sentient creatures, for ecosystems, and for the Earth's biosphere as a whole.

Because health and its maintenance necessarily employ the services of caregivers, another strand of research in the area of spirituality and health focuses on caregivers' own spiritual resources (Wright et al.) as they experience the ongoing, potentially exhausting exigencies of caring for others. Research on spirituality and ethics focuses on patients' rights when they receive care (Muldoon), particularly on patients' spiritual needs, and on arguments calling upon health care workers to provide spiritual resources to their patients. Researchers have also addressed the cultural dimensions of spirituality and healthcare, including immigrants' and minorities' experiences in the U.S. healthcare system (Andresen, Ahia). Finally, not all studies support the conclusion that spirituality functions favorably in supporting positive health outcomes. For example, a study published in 2001 by Kenneth Pargament, Harold Koenig, Nalini Tarakeshwar, and June Hahn demonstrates that patients who experience "religious struggle" (e.g., feelings that God has abandoned or punished them) experience a higher mortality rate than other patients.

As research at the interface of spirituality and health continues to gain acceptance within the medical community, patients' experience in the healthcare system may reflect improved sensitivity regarding their spiritual needs and concerns. Particularly at the end of life, or when confronted with traumatic or chronic conditions, patients may be expected to feel the need to understand their own experiences in the context of their religious or spiritual worldviews. Indeed, doing so may prove crucial to patients' recovery or their experience of peace at the time of death. Patients' families, too, may experience increased comfort when health care providers and medical institutions permit the incorporation of culturally appropriate religious or spiritual practices and explanations alongside the delivery of medical care in an effort to address their loved ones' suffering and existential questioning in an integrated and holistic manner. At the same time, religious worldviews that blame the sick for their own conditions are best avoided, not only because they have been demonstrated to increase mortality (as reported above), but also because justifying such interpretations theologically presents itself as a dubious endeavor, at best.

See also ALTRUISM; MEDICINE

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JENSINE ANDRESEN

SPIRITUALITY AND THE PRACTICE OF SCIENCE

The notion of spirituality pertains to the practice of science in two ways. First, the spiritual character of scientists sometimes informs the ways in which they conduct scientific research. Indeed, some scientists like the astronomer Johannes Kepler (1571–1630) regarded their scientific research as a type of spiritual discipline. Second, for practitioners of the human sciences the recognition of a spiritual dimension in the people they study can have implications for how they work. It is also plausible to posit a relationship between these two points. Scientists who acknowledge a spiritual dimension in their own experience are probably more inclined to regard spirituality as a relevant feature of the people they study. Likewise, scientists with no spiritual inclinations are probably less attentive to what others call the spiritual aspects of life.

The psychologists William James (1842–1910) and Sigmund Freud (1856–1958) respectively illustrate these tendencies. Religious experience figured prominently in James's corpus of psychological writings as it did in his own personal life. Freud professed no religious commitments himself and sought to explain religion in others with reductive appeals to ideas such as wish fulfillment and obsessional neurosis. The Augustinian monk Gregor Mendel (1822–1884) is an exception to the pattern of religious scientists attending to spiritual aspects of their subject matter because he formulated general principles of inheritance without speculation about applications to spiritual traits in human beings. Charles Darwin (1809–1882) is a partial exception to the pattern of nonreligious scientists having little sense for the spiritual dimensions of what they study. Even though he eventually lost his religious faith, he retained until his death a sense of wonder at the complexity and beauty of nature's ways, including evolution by natural selection.

In contemporary Western culture spirituality is an ambiguous and vague notion. Part of its ambiguity arises because many people using the term insist upon defining it in their own way for their own purposes. Part of its vagueness occurs because it is often defined by what it is not (e.g., religion) and in relation to terms in well-known dichotomies (e.g., spirit versus matter). Given the focus here on the practice of science, spirituality will be identified with reference not to the ontological dualism of classical Greek philosophy (e.g., spirit versus matter), but to the phenomenological differentiation of whole and part. Most scientists think that spirituality loses relevance to the practice of science insofar as it presupposes aspects of archaic worldviews.

The spirituality of human experience is conceived as having outer and inner aspects. Facing outward, human existence is spiritual insofar as one engages reality as a maximally inclusive whole and makes the cosmos an intentional object of thought and feeling. Facing inward, life has a spiritual dimension to the extent that it is apprehended as a project of a person's most enduring and vital self and is structured by experiences of sudden self-transformation and subsequent gradual development. These two formulations need not be rigidly separated. Their integration is well expressed in first-century C.E. Roman writer Seneca's dramatic ideal: *Toti se inserens mundo* ("Plunging oneself into the whole world"; *Epistulae ad Lucilius,* 66.6). Considered as a whole, the spiritual dimension of human life is the embodied task of realizing one's truest self in the context of reality apprehended as a cosmic whole, of attaining an optimal relationship between what one truly is and everything that is.

The human relationship to the whole of reality has been variously expressed. In *The Republic* (532b) Plato (c. 427–347 B.C.E.) attributed to philosophers a supramental apprehension (*dialektos* or dialectic) of goodness itself. In 1984, the biologist Edward O. Wilson coined the word *biophilia* to mean "an innate tendency to focus on life and lifelike processes" (p. 1). In mystic and naturalistic idioms respectively these phrases identify a relationship with the world that is facilitated by scientific knowledge but that is rife with wider meanings. These two thinkers hold that whether people attain this relationship has momentous consequences: Wise government is at stake for Plato and biological diversity for Wilson.

The Spirituality of scientists

The practical implications of the spirituality of scientists are consequent to characteristic metaphysical and methodological principles. Three are of special importance: holism, realism, and determinism. The Greek notion of *kosmos* (cosmos) as a limited, ordered whole provides the basic concept that Pythagorean and Platonic philosophy elaborated into a doctrine of metaphysical holism. Noting that diverse phenomena such as the movements of heavenly bodies, the harmonies of musical octaves, and the shapes of physical objects can be described with mathematical concepts, the Pythagoreans posited an underlying unitary numerical principal (*arithmos* or number). According to Aristotle (384–322 B.C.E.), some Pythagoreans gave such great priority to one numerical archetype—the *decad*—that they posited the "counter-earth" in order to instantiate it (*Metaphysics* 985b 22). When added to sun, moon, and the seven planets observable to the naked eye, the counter-earth became the tenth heavenly body. Practices like this have discredited naïvely metaphysical versions of holism, but the viewpoint survives in more modest methodological forms such as an aversion to descriptive forms of reductionism. Freud's reduction of religious phenomena to psychological factors is a prominent form of such reductionism.

Isaac Newton's *Philosophiae Naturalis Principia Mathematic* (Mathematical principles of natural philosophy) of 1687 proposed mathematical principles that govern "the system of the world." In a famous scholium in this work Newton set forth the absolute framework of space and time that is the precondition for the system. Although renowned for his aversion to speculative hypotheses (*hypotheses non fingo*) Newton offered no inductive argument for this absolute framework but, as in the case of the universal law of gravitation, he appealed informally to the will of God as an ultimate cause. Newton is typical of seventeenth-century scientists whose dual inheritance of Greek rationalism and biblical theism combined to give them great confidence that the world is real and orderly and that its order is knowable by human beings. Scientists whose spirituality posits reality as God's creation tend to find social constructionism uncongenial. For instance, ways of understanding religion similar to Peter Berger's and Thomas Luckmann's *The Social Construction of Reality* (1966) allow religion parity with other socially constructed phenomena but diminish its capacity to evoke awe and devotion. Sociological studies report higher levels of communal worship and private prayer among persons who identify themselves as traditionally religious than among more liberal religious persons and more diffusely spiritual respondents.

Many Western scientists have seen God's presence in providential care as well as in aboriginal creativity. Albert Einstein (1879–1955) is preeminent among such scientists in the twentieth century. Physicist Niels Bohr (1885–1951) said that Einstein once expressed reservations about a probabilistic interpretation of quantum mechanics by declining to consider "whether God plays dice with the universe." Einstein's commitment to deterministic explanations motivated him to seek an interpretation of quantum mechanics more compatible with his way of thinking than Bohr's idea of complementarity and Heisenberg's Uncertainty Principle. In a like fashion Einstein's good friend Kurt Gödel (1906–1978)—a mathematical Platonist—was not ready to allow his own limitative theorems to be the final word in mathematical logic; he preferred to think that more powerful axioms would one day be forthcoming. Spirituality sometimes motivates scientists to seek systems of thought more synthetic than those with which their colleagues are satisfied.

As the spirituality of contemporary scientists becomes less closely tied to classical philosophy and biblical theism, the commitment to traditional varieties of realism and determinism has waned. Fritjof Capra's *The Tao of Physics* (1975) is an example of this new sensibility and is notable for its embrace of both a metaphysical and methodological holism. Capra finds resources in Asian mystical traditions for a nonmaterialistic sort of realism and a nondeterministic conception of causality. Feminist thinkers have also offered alternatives to scientific worldviews emphasizing the domination and control of nature and the divorce of intellect from emotion and other noncognitive traits. Some feminist reinterpretations of scientific practice draw upon the experience of women scientists. For instance, Evelyn Fox Keller has clearly been influenced by the mystical elements in the character and practice of the biologist Barbara McClintock. Many contemporary ecofeminists are inspired by the spiritual approach to nature evident in the life and work of Rachel Carson (1907–1964).

The practice of science in understanding spirituality

Efforts of social scientists to attain scientific standing for their disciplines have proceeded along two different trajectories. The French positivist tradition of Auguste Comte (1798–1857) and Emile Durkheim (1858–1917) de-emphasized individual experience in favor of scientifically accessible features of human groups, and Durkheim pioneered the development of quantitative techniques for identifying regularities in social phenomena. In this context religion and spirituality are treated as epiphenomena that can be accounted for by more readily observable social, economic, and psychological factors. The German hermeneutic tradition of Max Weber (1864—1920) and Wilhelm Dilthey (1833–1911) gave more prominence to the scientist's intuitive understanding (*Verstehen*) of subjects who presumably share basic attributes and habits of valuations with their interpreters. For Weber a sociological law is "a statistical regularity that corresponds to an intelligible intended meaning" (quoted in Winch, p. 113). Efforts to understand religion and spirituality are paradigmatic of the challenge facing the social sciences (*Geistwissenshaften*) as Weber and Dilthey understand them. Religious phenomena such as God and salvation are not publicly observable and so must be apprehended by intuitive understanding.

The hermeneutic principle stating that any cultural artifact, such as a literary text or an architectural structure, should be interpreted in the context of the whole to which it belongs invokes the whole/part differentiation constitutive of the idea of spirituality described above. The most inclusive whole in which such understanding takes is often given spiritual meaning. The American philosopher Charles Sanders Peirce (1839–1914) did this with his novel ideas of *abduction* and *musement.* Abduction is a variety of inference (complementing induction and deduction) that consists of engendering and adopting a good explanatory hypothesis for a given phenomenon. It involves discovery more than justification. Musement occurs when people allow the powers of observation and reflection the liberty of "pure play." Peirce claimed that when musement is genuinely experienced it spontaneously gives rise to the "God-hypothesis" as the most basic hypothesis of human thought and the widest horizon in which human understanding occurs. Peirce was also a logician who advocated the view that scientific laws in both the natural and social sciences are ineluctably social and probabilistic. As with Capra's appeal to Asian mysticism, Peirce illustrates a spiritual sensibility that is scientific in a way that departs from classical realism and determinism.

Spirituality plays a role in the practice of science not only with regard to how statistical regularities are interpreted, but also with regard to how and why data is collected and analyzed. Efforts of epidemiologists, sociologists, and psychologists to understand the impact of various aspects of religiousness and spirituality on health outcomes illustrate the way in which studying spiritual subject matter influences scientific practice. For most of the twentieth century, epidemiologists were so disinclined to study the relationship between religion and health that one researcher, David Larson, described religion as the "forgotten variable." This same epidemiologist documented the high frequency with which religious phenomena illustrated psychopathologies in a recent version of the *Diagnostic and Statistical Manual of Mental Disorders* (*DSM*). Through the efforts of epidemiologists like Larson who acknowledge a spiritual dimension in both themselves and the people they study, epidemiological research into the relationships between religiousness and health is now funded and reviewed by agencies of the National Institutes of Health. Newer editions of the *DSM* have sought to provide a more empirical treatment of religion as factor related to mental health. In these specific ways the practice of epidemiology as a research activity has changed.

The results reported by epidemiologists about relationships between religion and health have also begun to inform clinical medicine and public health. Efforts toward "holistic medicine" predate the research of epidemiologists. For instance, the introduction of chiropractic techniques by Daniel David Palmer in the late nineteenth century were motivated by a conviction that health was dependent upon a free flow of "an intelligent force . . . usually known as spirit." Misplaced vertebrae impede the flow of spirit and so should be realigned. Chiropractic techniques are exemplary of spiritually motivated but demonstrably effective practices that have gradually been acknowledged by medical professionals, even when they reject the causal explanations underlying them. Meditation practices—often described more neutrally as relaxation or biofeedback techniques—have gained similar acceptance and for them epidemiological studies have provided empirical evaluations.

Public health practitioners have found that interventions addressed to communities, such as regular cancer screening and increased physical activity, are sometimes more effective at promoting healthy lifestyles than similar ones addressed to individuals. Results from epidemiological studies also show that religious people tend to have healthier lifestyles, with, for example, less use of tobacco and alcohol and more social support. Noting these points public health practitioners have started to work with religious communities, and especially with urban African-American churches, in order to implement disease prevention programs of various sorts. Seeing religious communities as potential partners rather than as ideological opponents is a major shift in public health policy and portends a productive change in public health practice.

Conclusion

In an influential 1948 World Health Organization document, health was defined as "a state of complete physical, mental, and social well-being and not merely as the absence of disease or infirmity." Some epidemiologists now advocate that spiritual well-being should be included in such comprehensive definitions. People, they contend, are never entirely free of disease or infirmity and so part of good health is the ability to cope with adversity. Religiousness has been shown to be associated with quicker recoveries from conditions like acute cardiovascular disease. It has also been shown to be associated with higher levels of life satisfaction and lower levels of pain in conditions like cancer, for which religion and psychosocial factors generally are less associated with quicker recoveries or longer survival. In conclusion, the impact of spirituality on the practice of science is most positive when it helps scientists be agents for achieving and understanding human well-being in its fullest sense and amidst the widest range of circumstances.

See also ARISTOTLE; DARWIN, CHARLES; ECOFEMINISM; EINSTEIN, ALBERT; FEMINISMS AND SCIENCE; NEWTON, ISAAC

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PETER VAN NESS

STEADY STATE THEORY

The Steady State Theory of the universe was put forward in 1948 by cosmologists Hermann Bondi (b. 1919) and Thomas Gold (b. 1920), who were later joined by Fred Hoyle (1915–2001). The theory was an alternative to the standard Big Bang cosmology of the day, which suggested that the universe has a finite age. Motivated openly by philosophical implications of a non-eternal universe, Bondi, Gold, and Hoyle sought to discover whether an alternate explanation for the astronomical observations that produced the Big Bang theory was possible. The theory proposed the continuous creation of new matter in the empty spaces of expanding space-time. The idea of continuous creation was argued to be less problematic than the dramatic singularity of the Big Bang, which the Steady State Theory could avoid.

The theory was largely abandoned after the discovery by Arno Penzias (b. 1933) and Robert Wilson (b. 1936) in 1965 of the microwave background radiation in the universe, which showed that the universe was much denser in the distant past, contrary to the predictions of the Steady State Theory. While the theory never gained widespread support it played an important role in the history of modern science. It helped to tentatively confirm the status of standard Big Bang cosmology, it showed the importance and necessity of seeking alternate theories, and it demonstrated that philosophical and even theological views can be significant sources of inspiration for scientific theories.

See also BIG BANG THEORY; CREATIO CONTINUA

MARK WORTHING

STEM CELL RESEARCH

Few topics in science and religion have been as hotly contested in recent years as stem cell research, largely because it involves the fate of, disposition of, and research on the human embryo. There are two basic types of stem cell research—that involving adult cells (AS cells) and that involving human embryonic cells (ESCs or hES cells); only the latter is a source of controversy. In both cases, research is still at the early stages regarding the programming and uses of these cells, and there is comparatively little data about the efficacy of AS and hES cells for human therapies. That is why most scientists agree that, in the United States, government funding should be widely available for research on both types of stem cells, an issue that has been contested in the U.S. Congress.

Stem cells are unspecialized and so are able to renew indefinitely; they also have the capacity to differentiate into specialized cells. In humans, these cells are found in some adult organs, in blood, and in bone marrow (Mezey et al. 2000; Bjornson et al.1999); in the inner cell mass of the human embryo at the blastocyst stage (five to six days after fertilization) (Thomson et al. 1998); on the gonadal ridge of aborted or miscarried fetuses (Shamblott et al. 1998); and in the placenta and umbilical cord (hematopoetic stem cells).

Because stem cells have the capacity to regenerate, particularly ESCs, they have ushered in the era of "regenerative medicine," signaling that, in theory, these cells can be used to regenerate human tissues and cells, and ultimately increase quality of life and the human life span. Embryonic stem cells are the progenitor cells for the human body and at their earliest stage (the blastocyst stage) they are completely undifferentiated and can give rise to any cell type in the human body (totipotent, pluripotent, and multipotent are all terms that have been used to describe this phenomenon). At this stage the cells have not yet received their "marching orders" for what they will become; therefore, scientists have been experimenting with controlling the programming of ESCs in culture in order to direct their ends (controlled differentiation) to specialized cells such as blood, skin, and nerve cells.

In order to extract these embryonic stem cells, scientists must collapse the trophectoderm that surrounds the blastocyst in order to get the stem cells from the inner cell mass (ICM) where they reside within the blastocyst or pre-embryo. Such a technique destroys the pre-embryo and renders it incapable of implantation in the uteran wall. This is the crux of the ethical problem for those who oppose embryonic stem cell research.

Studies in 2001 and 2002 indicate the potential for primate parthenotes to form embryonic stem cells and to develop a variety of differentiated cell types in culture (Cibelli et al. 2001; Holden 2002). Parthenotes are embryos that grow from unfertilized eggs (chemically tricked into fertilizing and retaining the full choromosomal complement) that are, so far as is known, incapable of becoming viable fetuses in primates and humans. Thus, scientists hope that this may prove to be an ethically uncontroversial way to obtain stem cells, allowing researchers to avoid therapeutic cloning as means to this end.

The ethical and religious issues surrounding stem cell research concern not so much the therapeutic ends of the research (cures for Parkinson's disease, juvenile diabetes, Alzheimer's disease, heart disease, and a host of other degenerative diseases); rather, the controversy surrounds the status of the human embryo and points to larger issues about what it means to be human and when life begins.

The Roman Catholic Church and conservative Protestant churches have made the strongest opposition to embryonic stem cell research of all religious traditions in the United States. The Catholic position is that life begins at conception; thus the human embryo is accorded the full rights and dignity of a human person from the very moment that the sperm penetrates the egg. Therefore, it is a grave sin to destroy any human embryo since the act constitutes destruction of life itself, a responsibility belonging only to God. Moreover, the Catholic Church has opposed the creation of human embryos for research purposes (therapeutic cloning, for example) for two reasons: To do so would be to treat human life as a mere means to an end, which is a violation of human dignity and the sanctity of life; and embryos ought only to be created in conjunction with the conjugal act of love within the context of marriage (natural law). (Donum Vitae 1987). It is important to note, however, that there are a variety of dissenting Catholic positions on this issue.

Conservative Protestant churches such as the Southern Baptist Convention and fundamentalist independent Christian churches have tended to join the Catholic protest against ESC research and have emphasized prioritizing AS research as an acceptable means to the end of regenerative therapies. The rationale for such opposition does not emphasize a natural law approach to ethics and emphasizes instead a biblical approach. An argument that the Christian tradition has a mandate to protect the weakest and most vulnerable members of society (the embryo in this case) is advanced by Lutheran theologian Gilbert Meilaender in his essay "Some Protestant Reflections" (2001).

On the other hand, mainline Protestant denominations (United Church of Christ, Episcopal, Presbyterian, Methodist) tend to be supportive of all stem cell research so long as the human embryo is treated with respect. In 2001, the General Convention of the Presbyterian Church voted to endorse embryonic stem cell research. Mainline Protestantism has focused on the great amount of good that can come of this research and on concerns of distributive justice to ensure that the poor will receive the benefits of stem cell research equally with the rich. Moreover, most mainline Protestants (and many Catholics) support using excess embryos for stem cell research. These embryos have been frozen in fertility clinics and would be thawed and discarded eventually if they were not put to what many believe is a good end—human healing. One Lutheran theologian who supports ESC research, in contrast to Meilaender's argument, is Ted Peters (Peters 2001).

Although there are three main branches of Judaism (Orthodox, Conservative, and Reform), and it is sometimes difficult to find agreement on bioethical issues, in this case most Jewish scholars are supportive of all stem cell research. This is due, primarily, to the fact that Judaism professes a strong mandate from God to heal and to reduce human suffering. Moreover, in Jewish law the embryo has no moral standing outside the womb; a developing embryo in laboratory culture is morally neutral until implantation. Therefore, the ends of all stem cell research appear to be morally coherent with Jewish ethics (Dorff).

Islam is also a diverse religious tradition. However, in general, Islam would be in favor of all forms of stem cell research since there appear to be no "recent rulings in Islamic bioethics regarding the moral status of the blastocyst from which the stem cells are isolated" (Sachedina). Islamic scholars have found that the Qur'an's focus is primarily on the developing fetus in the womb. Islam shares with Judaism a concern with human healing; thus, if ESCs hold real (not just speculative) potential for therapeutic healing, there would be no objection to proceeding with such research.

See also BIOTECHNOLOGY; CHRISTIANITY, ROMAN CATHOLIC, ISSUES IN SCIENCE AND RELIGION; CLONING; DNA; GENE PATENTING; GENE THERAPY; GENETIC ENGINEERING; GENETICS; JUDAISM; ISLAM

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SUZANNE HOLLAND

STRING THEORY

String theory, also called *superstring theory,* is, generally speaking, any physico-mathematical framework that describes fundamental physical reality in terms of superstrings *Strings* in this context should not be confused with *cosmic strings,* which are one-dimensional (string-like) regions of cosmic extent containing vacuum energy different from that of the true vacuum. The superstrings of string theory, in contrast, are extremely tiny loops, or possibly segments, that have been suggested as the most fundamental of all physical entities, and as the source of all other fields and particles.

Before the 1980s, the most fundamental entities were most often considered to be *particles,* which are zero-dimensional objects, but it has become clear that particle models do not provide a rich and flexible enough basis for fundamental quantum field theories; strings are much more suitable. More specifically, string theory provides promising candidates for an adequate quantum theory of gravity and, at the same time, for theories of the total unification of all four fundamental physical interactions (gravity, electromagnetism, and the strong and weak nuclear forces. Grand Unified Theory (GUT) will provide unification of the three nongravitational interactions.

Quantum mechanics (along with its extension to quantum field theory) and Albert Einstein's (1879–1955) theory of gravitation are two important pillars of contemporary physics. And yet, as they are presently formulated, they are deeply incompatible with one another. As of 2002, constructing a complete and adequate quantum theory of gravity has evaded the best efforts of theoreticians. Exciting and surprising work on superstrings since about 1984, however, has moved science much closer to achieving quantization of the gravitational field, thus resolving and healing this incompatibility. It is already clear that the leading string theory candidates yield general relativity as their low-energy limit. Essentially, this means that string theory, if successful, will become not only the quantum theory of gravity, but also the quantum theory of space and time, with crucial applications to early-universe cosmology.

It also appears likely that some version of string theory will at the same time unify all four fundamental physical interactions, including gravity, thus bringing to successful completion the much heralded quest for unification that motivated the physicist James Clark Maxwell (1831–1879), Einstein, and so many others. In order to accomplish this unification, the strings must manifest *supersymmetry*—they must be *superstrings.* Consider that all fundamental particles have either half-integral spin ($\frac{1}{2}$, $\frac{3}{2}$, . . .) or integral spin (0, 1, 2, . . .). The half-integral spin particles are called *fermions,* and constitute the building blocks of matter; protons, neutrons, electrons, and quarks are all fermions. The integral spin particles are called *bosons,* and are the force-carriers between the fermions, mediating the electromagnetic, gravitational, and strong and weak interactions. *Photons, W massive bosons, Z massive bosons, gluons,* and *gravitons* are the bosons that mediate the electromagnetic, weak, strong, and gravitational interactions, respectively.

Fermions and bosons satisfy different statistics and symmetries, and have to be treated differently in standard quantum field theory. The first seriously considered string theories—studied for purposes other than those for which newer superstring theories are studied—were bosonic strings, which only incorporated the symmetries and statistics of bosons. Obviously, if a theory is going to unify all particles and fields, it will have to incorporate the symmetries of both fermions and bosons within the same framework; it will have be *supersymmetric,* and the strings will therefore have be superstrings.

Where would the superstring description of reality be needed? Certainly, it would provide a detailed and physically complete explanation of all the characteristics and parameters of material reality, including their deep interconnections and their origins in the vibrations and interactions of the fundamental superstrings. It would, at the same time, provide an adequate description of material reality at temperatures higher than $1032 K, where the general relativistic description of space, time, and mass-energy breaks down. There was a time in the very early universe, immediately after the Big Bang, when those temperatures obtained and during which the physics of the universe was that of a single unified fully quantitized superforce. This era is referred to as the *Planck era,* after the German theoretical physicist Max Planck (1858–1947). In fact, it is only in such terms that the Big Bang itself, as well as the emergence or origin of space, time, and matter, can really be characterized.

Superstring theories resolve a number of difficult anomalies and divergences in quantum theory. But they also lead to some features that are, at first sight, puzzling. One of these is that they almost always require higher dimensions—for example ten or twenty-six—rather than the three spatial dimensions and one time dimension that characterize the low-energy world. How then can these superstring theories be reconciled with reality as we know it? The answer is straightforward but surprising. At very high energies or temperatures, such as immediately after the Big Bang, reality will be ten dimensional or twenty-six dimensional, as described by superstring theory. But, as the universe exits the Planck era, and enters the classical domain where gravity is adequately described by Einstein's general relativity and is no longer unified with the other interactions, the extra dimensions compactify (curl up into infinitesimal knots) leaving only the four-dimensional space-time with which we are familiar. Of course, if this is true, scientists should find some evidence of these extra curled-up dimensions. Such relics of the supersymmetric past would constitute powerful confirmation of superstring theories. This is an active area of research.

Relevance to theology

The relevance of string theory for the relationship between science and theology is clear, particularly in light of its applications to very early universe cosmology. First, a fully adequate string theory would give a complete unification and explanation of the laws of nature at the level of physics. In so doing, it would fill out the description of one of the most fundamental and pervasive sets of relationships through which God creatively acts in the universe. Secondly, it would give a much better description of the physics of the earliest phase of the universe's evolution, doing away with the initial singularity and helping scientists to speak more precisely about the origin of space and time, of all the laws of physics, and possibly of mass-energy. This would certainly help to delineate the limits of scientific explanation more compellingly. It is extremely unlikely, for instance, that the ultimately successful string theory will entail the existence of a unique universe or that it will explain why there is something rather than absolutely nothing, or that it will account for why there is this type of order, as specified by the string theory, rather than some other order. A clear appreciation of such limitations would enhance the understanding of the interactions, possible and desirable, between religion and science.

See also COSMOLOGY; GRAND UNIFIED THEORY; GRAVITATION; PHYSICS, QUANTUM; SUPERSTRINGS

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WILLIAM R. STOEGER

SUBJECTIVITY

See CONSCIOUSNESS STUDIES; EPISTEMOLOGY

SUFFERING

See EVIL AND SUFFERING

SUPERNATURALISM

The meaning and the history of the word *supernatural* depends entirely upon the order that it seems to supersede: the natural. The French Jesuit theologian Henri de Lubac (1896–1991), in his erudite and controversial book *Surnatural* (1946), provides a significant history of the transmission of the word. He informs us that it was only in the ninth century, with Carolingian translations of Pseudo-Dionysius (c. fifth century C.E.) and John Scotus Eriugena (c. 810–877), that the Latin word *supernaturalis* entered theology. Even then its usage was rare until the middle of the thirteenth century, and it did not come into standard use until after the Council of Trent in the middle of the sixteenth century.

History of the word and the concept in the West

The reason for the hesitancy of its use prior to the dawning years of modernity, before the rise of the secular as a domain distinct from the sacred and the physical as distinct from the metaphysical, was an older semantic resonance associated with the word *natural*. The early Christian fathers, in speaking of the difference between Adam's fallen state of sin and carnality and the salvation wrought in Christ, interpreted Adam and Eve's previous nakedness as the "natural" state. The "natural" was the human condition without sin; the pristine state in which was manifested the untarnished image of God. Such a natural condition was to be redeemed, not superseded. Even in the late sixteenth century, when the English poet and courtier Sir Philip Sidney (1554–1586), came to write his famous *Defence of Poesie,* the point could be made that poetry's efficacy lay in being able to transmute this corruptible world back into its pristine and idealized naturalness. The "supernatural" then arrives late in the cultural history of the West.

Early cosmology certainly conceived of realms, powers, and principalities beyond the mundane. The ancient Greeks had their notion of the heavens (*ouranios*) and even of a place above the heavens (*uperouranios*) from which the gods descended. Derived in part from Plato's *Timaeus* and Aristotle's *Physics,* the ultraheaven, and its synonym the hypercelestial (*uperkosmios*), announced a cosmological, epistemological, ethical, aesthetic, and ontological hierarchy. Everyday experience was mythologized as one traversed the lines between the visible and the invisible, the sensuous and the intelligible, the body and the soul. Such was the veneration for the ancients and for ancient knowledge (which was believed to be closer to the truth because nearer in time to Adam and Eve's experience in Eden), that this cosmology remained in place throughout Christendom until the maps of the universe were redrawn in the seventeenth century.

In the New Testament, the writer of the Gospel of John has Jesus speaking of the need to be born from above (*anothen*). In his first Letter to the Corinthian, in a series of distinctions between the body, soul, and spirit, Paul (himself experiencing a translation to the third heaven) writes of the celestial man (*anthropos ex ouranou*) whose image humans bear. This usage seemed to have sanctioned the adoption of the term, and its cosmological associations, by the early Greek fathers (particularly Clement of Alexandria (c. 150–215) and Origen (c. 185–254)). The celestial and hypercosmic as realms of the spiritual and divine became spheres occupied by Christ, the Spirit, and God himself. The term was translated directly into Latin, for we find Tertullian (c. 155–220) writing about Christ as supercelestial in *De carnis resurrectione.* Other Latin writers used *supermundialis* or *supermundanus* similarly. As with the ancient Greeks, the orders of existence differed in the celestial realms, and so Origen, and later Augustine of Hippo (354–430), described angels as having a supercelestial nature (*phusis*). Gradually, discussions begin to appear of the celestial essence (*uperousios, uperousiotes*) and descriptions of the Trinity as the super-essential. These words are translated in Latin as *supersubstantialis* and *superessentialis*. But it still remains significant that *supernaturalis* arrives much later, only to become the most common word of all.

What is different about *supernaturalis* is that it more explicitly defines a nature, powers, and dominions that are unearthly. There had, of course, been the dualistic myths of the Zoroastrians and, later, Gnostics, that had separated the forces in the world above from those operating in the sublunar realm. But despite the dualistic cosmology, the transit between the above and the below constituted a continuum. With *supernaturalis* a distinction was being made such that, by the seventeenth century, any incursions from the supernatural realm were understood as ruptures of the natural order. As such, *supernaturalis* could only gain currency as that which was *naturalis* came to be understood as the order of things in the postlapsarian, rather than the prelapsarian, world. This distinction arose in mediaeval theology.

For the medieval Christian philosopher Thomas Aquinas (c. 1225–1274) God is the supernatural truth contemplated by the fathers, the supernatural cause of all things, a supernatural principle whose effects are registered throughout the created world. These were not entirely separate, or even antithetical, orders of being as the latter participated in the former by being the effects of the God who maintained and sustained them. The participation of creation in the operations of the divine constituted the *sacramentum mundi.* Nevertheless, for Aquinas, theological knowledge as a divine science rested upon understanding the effects of God within creation as revealed in Christ, the operation and pedagogy of salvation. He distinguished such knowledge from the knowledge of created things in themselves, which was a natural science.

This distinction between knowledge on the basis of revelation and knowledge on the basis of observation led increasingly to a division of intellectual labor, and the examination of things created took on an independence that, ultimately, led to the establishing of "Nature." The Reformation emphasis upon faith as distinct from human reasoning, revelation opposed to fallen creation, called into question the older construals of the *sacramentum mundi.* So by the time of the Council of Trent (and the Catholic counterreformation), "Nature" was becoming an autonomous, rule-governed realm open for systematic enquiry, manipulation, and improvement. When the older Platonic and Ptolemaic cosmologies were being superseded, then the supercelestial lost its valance. The "supernatural" arrives as that which transcends the natural and is superior to the natural insofar as it is more powerful (for both good and evil) in being more spiritual.

Secularization and disenchantment

According to M. H. Abrahams, the contemporary understanding of the supernatural is a cultural product of early romanticism and the processes of secularization. With modernity and the authority given to human reasoning, the increasing exploration and cataloguing of the natural world, and with the continuing Protestant attacks upon superstition, the world became secularized.

Secularization brought about a demythologisation of human experience, just as the technological calculation and manipulation of the world brought about what the sociologist and economist Max Weber (1864-1920) termed its "disenchantment." The process of disenchantment took place through the systemic rationalization of observable (and therefore verifiable) phenomena. The early romantics were themselves reacting against the stripping of the world of its mysteries and mythologies—the world according to the mathematics and mechanics as Isaac Newton (1642–1727) conceived it and the industrial revolution constructed it.

In an early essay titled "Language and Human Nature," the philosopher Charles Taylor wrote of a distinction between two views of the world, the objectivist and the expressivist. In premodern cosmologies what was real was expressive of creation's divine and spiritual origins. But from René Descartes (1596–1650) onwards the world was not viewed in terms of its theological provenance, but in terms of what the human subject observed. Objectivism conceived the world as a realm of contingent, neutral facts that could be gathered encyclopedically. Materiality lost its translucence and became opaque. Objects lay passive beneath the scrutinizing gaze of a subject who calibrated and catalogued them. This objectivist realm, from the seventeenth century onwards, became nature and all its values, laws, and dynamics were immanent and self-manifesting. The natural was that which presented itself to the senses and could therefore be examined by empirical science. It was a state that lent itself to systematic explanation. Nature could be made to deliver up whatever secrets it contained so that people might learn how the use them to their own advantage.

A new functionalist, instrumentalist, pragmatic, and utilitarian approach to the world cut creation free from a dependency upon a creator. In doing this a series of further divisions followed: subject and object, the cultural and the natural, the private and the public, the freedom of enlightenment and the dangerous darkness of ignorance. The supernatural was born of these new binaries. It was conceived as the opposite of the natural, that which stood outside of the rational and integrated orders of nature. The supernatural was then irrational, disordered, a realm of darkness, ignorance, and superstition. Religion—a conceptual category also coined during this time—was to be purged of these cruder, mythological elements and refigured, as the philosopher Immanuel Kant (1724–1804) termed it, within the limits of reason alone. As such, religion—a private devotion that no longer trespassed on public truth—was clawed back from the supernatural. Catholicism, with its liturgical and doctrinal commitment to the sacramental world view, was repeatedly condemned by both deists and Protestants for its supernaturalism and its promotion of superstition.

Re-enchantment

The supernatural as it emerged from the gothic imagination came to be defined as a realm of forces and dominions beyond the human. These forces and dominions are either mythically organized in some cosmic battle between good and evil (angels, demons, wizards, and vampires) or make manifest another dimension following death (ghosts, hauntings, and intimations of heaven). Both of these forms of the supernatural have a history within the Western tradition, but, as Mark Edmundson has noted, what is striking in contemporary Western and Eastern cultures is the resurgence of that gothic imagination.

There has been a cultural shift with respect not only to the credibility of the supernatural but also to its interface with the everyday. Postmodernity, as the sociologist Zygmunt Bauman observes, has re-enchanted the world. The everyday is again being mythologized, such that where once C. S. Lewis placed his supernatural world of Narnia on the far side of the wardrobe, the writers Philip Pullman and J. K. Rowling have their supernatural worlds investing the ordinary. Furthermore, the scientific reasoning that Weber saw as fundamental to the process of disenchantment plays an important role in the re-enchantment of the world. In the popular imagination the cyborg, the clone, the alien, and the android have all joined the traditional array of supernatural figures. Science has absorbed the supernatural, as more and more cyberspace games trade in gothic fantasies, and the exhilaration of surfing the net is being described in terms once reserved for mystical experiences of self-transcendence.

See also NATURALISM; NATURE; THOMAS AQUINAS

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GRAHAM WARD

SUPERSTRINGS

Superstrings are extremely tiny, theoretically postulated, one-dimensional loops or segments that are conceived as being the most fundamental physical entities, superseding point particles in that role. All other particles and fields, both bosonic (integer spin, interaction carrying) and fermionic (half-integer spin, matter constituting), are then considered to be the result of the vibrations and interactions of these superstrings. Superstring theories hold the best hope for unifying quantum theory with Albert Einstein’s General Relativity. They should at the same time effect the total unification of the four fundamental physical forces: electromagnetism, the weak and strong nuclear interactions, and gravity. These fundamental objects are called *superstrings* instead of just *strings* because they manifest *supersymmetry,* which means that both bosons and fermions are treated within the same mathematical framework, or symmetry group.

See also STRING THEORY

WILLIAM R. STOEGER

SUPERVENIENCE

Ever since Donald Davidson introduced the notion of supervenience within the philosophy of mind in 1970, it has come to play a key role in philosophical discussions regarding reducibility and the ontological structure of the world in general. With its help, philosophers of mind, in particular, hoped to solve the question of whether a nonreductive kind of materialism could be upheld that would avoid the pitfalls of traditional dualism on the one hand and of traditional materialism on the other. The key attraction of supervenience was that it seemed to deliver dependence without reduction. Events at higher levels of reality could thus be seen as totally determined by lower-level events without higher-level laws of the so-called special sciences being reducible to physics.

Definition and types

In a loose sense, the core idea is as follows: B-properties (e.g., mental properties) supervene on A-properties (e.g., physical properties) if any two possible situations identical in their A-properties are identical in their B-properties. In other words, the B-facts "come along with" the A-facts, hence supervenience. The term is derived from the Latin words *venire* (to come) and *super* (on top of). Thus, if B-properties supervene on A-properties, then once the A-facts are fixed, the B-facts are fixed. They are automatically put in place as soon as the lower-level properties are put in their place. This is because, where supervenience reigns, there is no room for variation of the higher-level properties independently of the lower-level (e.g., physical) properties. In this way supervenience yields ontological dependency relations. At the same time supervenience has also been supposed to bar reducibility, thus freeing the way for a novel nonreductive brand of materialism in the philosophy of mind and, more generally, allowing special sciences to be autonomous without abandoning, as in traditional dualism, a unified materialist picture of the world.

The dependency relations enabled by supervenience may in fact vary in strength depending on the specific kind of supervenience relation involved. The above definition of supervenience, in effect, generates in its turn four different kinds of supervenience relations. First, the word *situation* as used in that definition may refer either to individuals or to entire worlds. Accordingly, local and global supervenience must be distinguished. Secondly, the word *possible* may refer to either logical or nomological possibility, giving rise to logical versus natural supervenience.

For the former distinction between local and global supervenience, consider an animal and its molecular "twin" (a molecule-by-molecule replica of the given animal). Although they must share the same shape, they do not necessarily share the same degree of fitness, since they do not necessarily share type-identical environments. Hence, shape, but not fitness, supervenes locally on physical properties. However, fitness does supervene globally on physical properties. When all the physical facts of this world are duplicated so that molecular twins will also be located in type-identical habitats, then physical duplicates must share exactly the same degree of fitness.

Clearly, local supervenience is the stronger of the two supervenience relations. Properties that are locally supervenient must also be globally supervenient, but not vice versa. Conversely, many more properties turn out to be dependent on lower-level properties when considered under broad conditions of global supervenience than when they are considered in local isolation, so to speak, regardless of context. Thus it can easily be seen that if we duplicate all the physical facts of the entire universe down to the minutest details of the distribution of microphysical properties in space and time (and we do nothing else), then all the biological facts of our world will be duplicated as well. Since the physical "recipe" of our world fixes all its objects, including the way they move and function and the way they physically interact, it, in effect, also fixes the biological facts. Even God could not have created a world that was physically identical to ours but biologically distinct. There simply is no logical space for the biological facts to vary independently of the physical facts of our world when considered in *toto*. Furthermore, since this holds for any logically possible physical duplicate of our world, it follows that biological properties logically (globally) supervene on physical properties.

This is a remarkable result. One may well wonder whether under such broad conditions of global supervenience there can be any property at all that could fail to supervene on the (micro-) physical facts of an entire world. If not, physicalist materialism would carry the day. This brings us to the second distinction mentioned above, the distinction between logical and natural supervenience. This is the more interesting distinction because it leads straight into highly controversial territory. Generally speaking, B-properties naturally supervene on A-properties if any two naturally possible situations with the same A-properties also have the same B-properties. In other words, in the case of natural supervenience, the B-facts are nomologically, though not logically, implied by the A-facts. That is to say, in possible worlds that are governed by the same natural laws as the actual world, the A-facts naturally necessitate the B-facts (assuming natural supervenience). Clearly, natural possibility is much stricter than logical possibility. For example, a (stable) cubic kilometer of uranium-235 is logically, but not naturally, possible. The critical question then is: Are there any (higher-level) properties that accompany the physical facts in all naturally possible worlds without being fixed by the physical facts in all logically possible worlds? And the controversial answer given by some philosophers is: Consciousness is such a property. On the one hand, they argue, consciousness at least naturally supervenes on the physical facts because any two physically identical creatures in the natural world will presumably have qualitatively identical phenomenal experiences. Nevertheless, these philosophers go on to argue, consciousness fails to supervene logically on the physical facts of our world. Here they appeal to two famous thought experiments. It seems entirely conceivable that a creature physically identical to a conscious creature might lack consciousness altogether (like a zombie), or might have experiences qualitatively very different from ours (they might have so-called inverted qualia, so that, for example, they might have our sensation of phenomenal red when looking at the sky). Therefore, if these two intuitions hold, materialism is false. A full account of the physical facts of our world, including a specification of the minutest details of the distribution of its microphysical properties over space and time, would yet leave entirely undetermined the quality, even the existence, of the phenomenal properties of our world.

Principle of multiple realizability

As discussed above, supervenience may yield ontological dependency relations of varying degrees. But how do things stand with respect to the other philosophical benefit reputedly reaped from this recently developed notion of supervenience, that of barring reducibility? This becomes apparent when one focuses on the converse relation implied in the definition of supervenience. Assuming supervenience, while two situations cannot differ in their B-properties without a corresponding difference in their A-properties, the converse does not hold. That is to say, type-identical B-situations may be realized by an indefinite variety of type-different A-situations. In other words, the notion of supervenience brings in its wake an important corollary notion, that of multiple realizability. And again, this feature holds special interest for the philosophy of mind because multiple realizability is just what we expect in the mental realm. Pain in humans may be realized by C-fibers firing, while in dolphins it may be realized by D-fibers firing without ceasing to be just another simple instance of pain. Indeed, the situation may be vastly more diverse and confusing at the physical level than this example suggests: Your headache may be physically realized differently from mine, as, for that matter, may my headache today versus my headache tomorrow. Similarly, the property of being a monetary transaction, which is a unitary concept at the level of economics, may be physically realized by a wide variety of physical events lacking any perspicuity or explanatory integrity at the level of physics. Accordingly, the predicates of a given special science will only map onto predicates of physics that are at best wildly disjunctive. Thus, inasmuch as supervenience entails multiple realizability, higher-level supervening properties turn out to be irreducible. In psychology, in particular, it has been argued, there cannot be any type-type identities between mental properties and the physical properties realizing them. Nor, consequently, is there any room for strict psychophysical laws so as to reduce psychology to neurophysiology and ultimately to physics. In general, supervenient properties, in spite of being ontologically dependent upon their subvenient base properties, retain their ontological and explanatory autonomy.

Principle of multiple supervenience

The above argument for irreducibility appealed to supervenience in connection with the corollary notion of multiple realizability. More recently, however, supervenience has also been invoked in an antireductionist line of argument deemed to be more effective, in which the crucial corollary notion was not multiple realizability but rather multiple supervenience. An analogy with dispositional properties may clarify the point. Usually one and the same categorical base may "realize" more than one disposition. Even so, only one of those will be causally relevant for a given event. Thus, Sally's death is related to the electrical conductivity of her aluminum ladder. But the categorical base thereof (the cloud of free electrons permeating the metal) also "realizes" such diverse dispositions as the thermal conductivity or the opacity of the metal. Clearly, the correct explanation for the tragic accident would be the one that cited the relevant disposition, not just the categorical base property. Thus explanations couched in terms of supervenient properties (dispositional or otherwise) cannot be reduced to explanations citing no more than the corresponding base properties. But the important point in this context is that the irreducibility in question clearly does not consist in the fact that these higher-level properties may be multiply realizable, but precisely in the opposite fact that a given categorical base property does not identify which of the higher-level properties realized is explanatorily relevant in a given case. In other words, it is not multiple realizability but rather multiple supervenience of macroproperties onto one and the same subvenient categorical base that necessitates citing that supervenient property, which is responsible for the given effect. Similarly, if the aluminum ladder had been exposed to the heat of the sun for a while, it would have been the thermal conductivity, not the electrical conductivity, that would have been causally responsible for Sally's burning her feet, as the case might have been, even though either disposition is realized in the very same categorical base. Thus the special character of higher levels of organization in nature can be vindicated in principle, and perhaps even more effectively, by invoking multiple supervenience in addition to the more conventional appeal to multiple realizability. Such hierarchical levels necessitate the need for macroexplanations with the causal depth and the theoretical appropriateness corresponding to the grain of the explanatory level in question.

In sum, supervenience affords the insight that macrocausation is a real force in nature at multiple levels of existence. Consequently, downward causation may be assigned a stable place in our picture of how the world is organized without upsetting our conception of the various domains of physics as constituting a closed and complete system of physical events at the physical level of description.

See also CONSCIOUSNESS STUDIES; DOWNWARD CAUSATION; MIND-BODY THEORIES; MIND-BRAIN INTERACTION; NEUROSCIENCES

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SYMBIOSIS

The term *symbiosis,* from the Greek words *syn* (together with) and *bios* (life), refers to different kinds of organisms living together in ongoing physical association. Although symbiosis is a fundamental biological relationship, it was a disputed concept until the late 1800s, and the term was only first used in 1878. Its role in ecology and evolutionary theory is still developing.

Biologists recognize several variations of symbiotic association. *Obligate symbiosis,* such as the tropical reef relationship between Zooxanthellae algae and the coral they inhabit, is necessary for the survival of one or more partners. *Facultative symbionts* are optional; in tidepools, some sea anemones have green flecks of algae growing inside them, while neighboring anemones do not. *Endosymbiosis* occurs when one species lives inside another, as cellulose-digesting bacteria inhabit the gut of herbivores. *Ectosymbiosis,* which does not involve internalization, occurs when, for example, birds or fish clean larger species. Finally, there is a range of interactive impacts. In *mutualism,* both species benefit; all the above and what is perhaps the first-described case, the algae-fungus association that forms lichens, are examples of mutualism. *Commensalism* involves advantage to one species and neutral impact on another. *Parasitic symbiosis* benefits one species at a cost to another. Some biologists use the term symbiosis only for mutualistic associations, although scholarly literature and popular textbooks are ambiguous on this point.

Symbiosis was catapulted to prominence in evolutionary theory by the notion that mitochondria and chloroplasts (internal organelles within cells) originated through the endosymbiotic internalization of simpler prokaryotic cells. This theory has been championed by Lynn Margulis, who developed the *serial endosymbiosis theory,* which attempts to account for the successive development of all eukaryotic cells (cells with nuclei), through a sequence of unions between various prokaryotic bacteria (non-nucleated cells). While some details of serial endosymbiosis theory are still debated, the endosymbiotic origin of eukaryotes is found in virtually all textbooks.

Symbiosis theory has been extended in several profound but controversial ways. The notion of *symbiogenesis* suggests that symbiosis contributes significantly to the origin of novel traits and new species. Traditional Darwinian theory argues that speciation occurs by natural selection operating on random genetic mutations. Symbiogenesis posits that the symbiotic union of diverse genetic information is a source of creative novelty on which selection acts. Some symbioses, such as lichens, result in an altogether different kind of organism. Moreover, instead of the win-lose scenarios of competitive individual selection, symbiogenesis may more readily create win-win cooperative scenarios that entail new capabilities and resources. Symbiosis as a major evolutionary mechanism has significant though still debated implications, especially for notions of cooperation and complexity in evolutionary history.

Another provocative extension of symbiosis theory entails the scale at which symbiotic associations are conceived to exist. Traditional examples of symbiosis involve individual organisms in physical association with other individuals: for example, a plant and the nitrogen-fixing fungi in its roots. However, one could think of symbioses as involving groups of organisms, such as oxygen-breathing animals and oxygen-generating plants in a pond community. In principle, this could be extended to communities interacting in an ecosystem, or global ecosystems interacting with each other on a planetary scale. James Lovelock's notion of Gaia holds that the entire living world, or biosphere, interacts to regulate water, atmospheric gasses, pH, and temperature. Margulis and others suggest that this reflects the symbiotic integration of life into a global superorganism.

See also COMPETITION; EVOLUTION, BIOLOGICAL

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SYMMETRY

In the most general sense, *symmetry* can be defined as a property that an entity has whereby it preserves some of its aspects under certain actual or possible transformations. A sphere is symmetrical because a rotation about its axis preserves its shape. A crystal structure is symmetrical with respect to certain translations in space. The existence of symmetries in natural phenomena and in human artifacts is pervasive. However, nature also displays important violations of symmetry: Some organic molecules come only or predominantly in left-handed varieties; the bilateral symmetry of most organisms is at best only approximate.

The general concept of symmetry applies not only to objects and their collections, but also to properties of objects, to processes they may undergo, as well as to more abstract entities such as mathematical structures, scientific laws, and symbolic and conceptual systems, including mythology and religion. Symmetry symbols pervade ancient cosmologies. Thus the concept of *axis mundi* (the world axis) is a famous mytho-poetic archetype expressing the idea of centrality in the arrangement of the Cosmos. Whether *axis mundi* is represented as a sacred mountain, tree, or ladder, it invariably signifies a possibility for humans to connect with heaven. The central image of Christianity, the cross, belongs in the same broad category, as far as its symbolic connotations are concerned. The concept of *triadicity* so essential to many religions is closely linked to symmetry considerations.

The abstract notion of symmetry also lies at the very foundation of natural science. The fundamental significance of symmetries for physics came to the fore early in the twentieth century. Prior developments in mathematics contributed to this. Thus, in his Erlangen Program (1872), the German mathematician Felix Klein (1849–1925) proposed interpreting geometry as the study of spatial properties that are invariant under certain groups of transformations (translations, rigid rotations, reflections, scaling, etc.). Emmy Noether (1882–1935) applied Klein's approach to theoretical physics to establish in 1915 a famous theorem relating physical conservation laws (of energy, momentum, and angular momentum) to symmetries of space and time (homogeneity and isotropy). By that time, Albert Einstein's (1879–1955) Theory of Relativity had engendered the notion of *relativistic invariance,* the kind of symmetry all genuine physical laws were expected to possess with respect to a group of coordinate transformations known as the *Lorentz-Poincaré group.* With this came the realization that symmetry (invariance) is a clue to reality: Only those physical properties that "survive" unchanged under appropriate transformations are real; those that do not are merely *perspectival* manifestations of the underlying reality.

With the development of particle physics the concept of symmetry was extended to internal degrees of freedom (quantum numbers), such as *C* (charge conjugation, the replacement of a particle by its antiparticle) and isospin (initially the quantum number distinguishing the proton from the neutron). Along with *P* (parity, roughly a mirror reflection of particle processes) and *T* (time-reversal operation), these were long believed to be exact symmetries, until the discovery in 1956 of *C*- and *P*-symmetry violations in certain weak interactions, and the discovery in 1964 of the violation of the combined *CP*-symmetry. However, theoretical considerations preclude violation of the more complex *CPT*-symmetry.

The emergence of quantum electrodynamics (QED), the first successful quantum relativistic theory describing the interaction of electrically charged spin-1/2 particles with the electromagnetic field, made the notion of gauge symmetry central to particle physics. The exact form of interaction turns out to be a consequence of imposing a local gauge invariance on a free-particle Lagrangian with respect to a particular group (U(1) in the case of QED) of transformations of its quantum state. Extending this principle to other interactions led to the unification of electromagnetic and weak forces in the Weinberg-Salam-Glashow theory on the basis of the symmetry group SU(2) × U(1) and to quantum chromodynamics (a theory of strong quark interactions based on the group SU(3)), and eventually paved the way for the ongoing search for a theory unifying all physical forces.

See also LAWS OF NATURE

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YURI V. BALASHOV

SYSTEMS THEORY

Systems science emerged as a response to the need for finding ways of understanding and dealing with complexity. The expanding orientation of systems thinking enables a quest for connections and meaning that can expand the boundaries of what traditionally has been considered science. Systems thinking has been compared to Buddhism, and evolutionary systems thinking can be appreciated as the integration of the sciences with the works of mystical and transpersonal thinkers such as Sri Aurobindo (1872–1950) in the East and Carl G. Jung (1875–1961) and Pierre Teilhard de Chardin (1881–1955) in the West. This convergence of science, philosophy, and religion is manifested in the systemic inquiry on conscious evolution and its underlying ethic.

This entry reviews the core ideas within systems science, and in particular the development of General Systems Theory (GST) as a cornerstone of the systems movement. General Evolution Theory (GET) is introduced as the natural unfolding of GST in the study of complex dynamic systems. The emergent view of evolution has implications for the understanding and guidance of human systems and can become the basis for the integration of critical insights for science, philosophy, and religion to surface a new global ethic. Having become conscious of the evolutionary processes of which human beings are a part, and with a sense of awe and responsibility, the challenge is to learn to "dance to the rhythms of evolution" for the purposeful creation of a sustainable and evolutionary future.

The emergence of systems science

In the 1920s,a handful of scientists from different fields became aware of the potential to develop a general theory of organized complexity. The biologist Ludwig von Bertalanffy (1901–1972) formulated the fullest expression of the emerging systems field in his General System Theory (GST). According to Fritjof Capra, Bertalanffy's work "established systems thinking as a major scientific movement (p. 46)" that responded to the limitations of modern analytical science and enabled a broader conception of science.

Analytical (as opposed to holistic) *reductionism* prevailed as the most central principle of scientific inquiry during the eighteenth and nineteenth centuries. Reductionism involves analysis of the isolated elements of the phenomena under study and seeks objectivity, repeatability of results, and refutation of hypotheses in order "to provide explanations for the new unknown, in terms of the known" (Checkland, p. 64). However, "the emergence of new phenomena at higher levels of complexity is itself a major problem for the method of science, and one which reductionist thinking has not been able to solve" (p. 65).

Systems science emerged from interdisciplinary studies and is characterized by a diversity of perspectives, foci, and approaches. Systems science is not a discipline, per se, but a meta-discipline or field whose subject matter—organized complexity—can be applied within virtually any particular discipline. Systems science has become the broader scientific area that embodies all the thinking and practices derived from, and related to, advances in systems theory, methodology, and philosophy. The main professional association dedicated to the study and the advancement of this area is the International Society for the Systems Sciences (ISSS). When established in 1954 by von Bertalanffy, Ralph Gerard, Anatol Rapoport, James G. Miller, and Kenneth Boulding, it was originally called the Society for the Advancement of General Systems Theory.

General system theory

A *system* is a set of interconnected components that form a whole and show properties that are properties of the whole rather than of the individual components. This definition is valid for a cell, an organism, a society, or a galaxy. Therefore, as Joanna Macy expressed it, a *system* is less a thing than a pattern. Systems thinking uses the concept of *system* to apprehend the world. It "is a framework of thought that helps us to deal with complex things in a holistic way" (Flood and Carson, p. 4). When formalized in explicit, conventional and definite form, it can be termed *systems theory.*

Systems theory provides a knowledge base that goes beyond disciplinary boundaries; it seeks isomorphism between and among concepts, principles, laws, and models in various realms of experience; it provides a framework for the transfer and integration of insights relevant to particular domains of research; and it promotes the unity of science through improving communication among disciplines. Bertalanffy's General System Theory (GST) is "a theory, not of systems of a more or less special kind, but of universal principles applying to systems in general" (Bertalanffy, p. 32). GST "aims to provide a framework or structure of systems on which to hang the flesh and blood of particular disciplines and particular subject matters in an orderly and coherent corpus of knowledge" (Boulding, p. 248).

General systems theorists acknowledge that specialized knowledge is as important as a general and integrative framework. Specific systems theories have emerged and include cybernetics, autopoietic systems theory, dynamical systems theory, chaos theory, organizational systems theory, and living systems theory, among others. Considered together, these specific systems theories comprise the systems sciences, many of which have become known as the so called new sciences or sciences of complexity.

General evolution theory

Following the systems tradition, General Evolution Theory (GET) looks for isomorphisms in the patterns of irreversible change over time at different systems levels. GET postulates that the evolutionary trend in the universe constitutes a "cosmic process" specified by a fundamental universal flow toward ever increasing complexity.

Evolution manifests itself through particular events and sequences of events that are not limited to the domain of biological phenomena but extend to include all aspects of change in open dynamic systems with a throughput of information and energy. In other words, evolution relates to the formation of stars from atoms, of Homo sapiens from the anthropoid apes, as much as to the formation of complex societies from rudimentary social systems. The process involves periods of dynamic stability (homeostasis), and when this stability can no longer be maintained, the system enters a period of turbulence—or bifurcation—when it self-organizes into a higher level of organization, structural complexity, dynamism and autonomy—or else, it devolves. In this way, complex open systems become more dynamic, more in control of themselves and of their environment, moving further and further away from the inert state of equilibrium.

The understanding of dynamic complexity, emergence, and self-organization manifested in general evolutionary processes has important implications for human activity systems. Ilya Prigogine and Isabelle Stengers reflect on the social threats and possibilities implied by an understanding of nonlinearity by recognizing that in "our universe the security of stable, permanent rules are gone forever. We are living in a dangerous and uncertain world that inspires no blind confidence. Our hope arises from the knowledge that even small fluctuations may grow and change the overall structure. As a result, individual activity is not doomed to insignificance" (Prigogine and Stengers, p. 313).

Human science and conscious evolution

Human science makes reference to an inclusive approach to the study of human phenomena that uses multiple systems of inquiry, including descriptive studies and prospective interventions. According to Marcia Salner, discussion about human science "was once conducted on the grounds of philosophy, professional researchers who must face up to practical problems of social survival are pragmatically moving toward what will work to provide answers where no reliable guides exist. . . . How we understand our world, how we learn about it, how we teach the young about their place in it, have consequences for our survival in it" (p. 8). Only a science that is both humanistic and systemic can deal effectively with complex human challenges and create evolutionary opportunities for human development in partnership with Earth.

Human science involves both systems (within the systems field) and systemic (outside the systems field) approaches. On the one hand, it involves the application of systems theories and methodologies in order to understand, ameliorate, and transform social systems. On the other hand, human science also incorporates systemic and holistic approaches, beyond the systems field, that challenge traditional assumptions about knowledge and science. For instance, critical theory seeks to combine philosophy and science, idealism and realism, and concepts and experiences to confront social injustice. Feminism seeks the emancipation of women for the betterment of humanity as a whole through the promotion of issues such as sexual equality, development, and peace. Scholars interested in qualitative research are articulating a comprehensive epistemology for a participatory paradigm that involves different ways of knowing.

What is common to all these alternative approaches is their holistic character and their commitment to bridge theory and practice for understanding and transforming social realities.

Following the trend in systems science of looking for theoretical and methodological complementarity, there are approaches that seek to integrate the knowledge base of systems thinking, general evolutionary processes, and human science. Evolution, both as a scientific theory and as a universal myth, is a powerful story for the transformation of consciousness and society. The implications of this knowledge base provide rich opportunities for manifold inferences for social action and research. First, humans do not need to be the victims of change— change can happen *through* humans, not *to* humans. Second, the future is not probabilistic, but rather, possibilistic: Humans can influence the direction of change through their intentions and actions. Third, for the first time in human history, human beings can experience joy "while working for the most ambitious goal available to the human imagination: To blend our individual voice in the cosmic harmony, to join our unique consciousness with the emerging consciousness of the universe, to fold our momentary center of psychic energy into the current that tends toward increasing complexity and order" (Csikszentmihalyi, p. 293). Indeed, science and spirituality are coming together in the ultimate exploration of the meaning and purpose of human existence: Conscious evolution—the evolutionary phase in which a developing being becomes conscious of itself, aware of the processes of which it is a participant, and begins voluntarily to co-create with evolution.

A new global ethic

"If our society is not working well," Lester Milbrath reflects, "we get the message that we need to rethink our value structure" (Milbrath, p. 67). Scientists and religious leaders agree: A new global ethic is required if human misery and irreversible damage to the planet is to be avoided.

Regardless of postmodernist or relativist positions, Mihalyi Csikszentmihalyi reflects on how similar are the world's major moral systems. He believes that "we have to find an appropriate moral code to guide our choices. It should be a code that takes into account the wisdom of tradition, yet is inspired by the future rather than the past; it should specify right as being the unfolding of the maximum individual potential joined with the achievement of the greatest social and environmental harmony" (Csikszentmihalyi, p. 162). From a systemic and evolutionary perspective, a multilevel ethic would promote:

(1) Human actions that benefit (or at least not harm) the individual—it must promote personal freedom;

(2) Human actions that benefit (or at least not harm) society—it must promote social justice;

(3) Human actions that benefit (or at least not harm) the planet—it must promote ecological harmony.

To focus exclusively on one level corresponds to what Carolyn Merchant has called egocentric, homocentric, or ecocentric ethics, respectively. The challenge is to strive for the ideal of a multilevel ethical approach that promotes what is good for the whole of individual humans, societies, ecosystems, and future generations at the same time, in order to promote sustainability in an evolutionary sense. In other words, as Evrin Laszlo proposes, to live simply and meaningfully allowing other people and other species to live with dignity as well, so that a favorable dynamic equilibrium in the evolution of the biosphere can be reached and sustained.

An important aspect of this new emerging ethic is its process orientation. Rather than considering morality as a set of static norms and rules, it should be embraced as an ongoing inquiring process, a conversation as suggested by West C. Churchman, in which human values are neither relative nor absolute. In the past, philosophy and moral inquiry have been restricted to a privileged minority of mainly white men. An ethical society requires that every member of society become a lifelong learner engaged in the ongoing ethical conversation that purposefully informs the actions and decisions that shape the present and the future.

Science is evolving. The convergence between systems views and mystical views allow a more comprehensive and meaningful articulation of the human-as-part-and-process-of-cosmos story. This "New Story," as theologian Thomas Berry calls it, can guide people in the adventure of ethically evolving human systems.

See also COMPLEXITY; EVOLUTION; VALUE, VALUE THEORY

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KATHIA CASTRO LASZLO

T

T = 0

The common notation $t = 0$ simply means "time equals zero." It expresses the radical and fundamental conclusion of standard Big Bang cosmology. It recognizes the connection between space and time by implying that the Big Bang did not occur *in* time but that time began with the Big Bang singularity. For many theological thinkers, the scientific articulation of $t = 0$ has significant implications for understanding creation, particularly the idea of a creation out of nothing (*creatio ex nihilo*).

See also BIG BANG THEORY; COSMOLOGY, PHYSICAL ASPECTS; CREATIO EX NIHILO

MARK WORTHING

TACIT KNOWLEDGE

Though it is a psychological fact that human beings acquire, retain, and employ tacit knowledge, accounts of its nature and function in perception, memory, cognition, language, and learning vary across disciplines. In epistemology, the concept of tacit knowledge was pioneered by the scientist and philosopher Michael Polanyi (1891–1976) in his *Personal Knowledge* (1956) and *The Tacit Dimension* (1966). Drawing on Gestalt psychology, Polanyi developed a theory of tacit knowledge by extending the perceptual model of attending *from* subsidiary clues or particulars (bodily processes, sensory experiences, memory, intimations) *to* a focal whole (pattern, object, entity) to a general model that holds cognitive processes ranging form identifying objects, performing skills, solving (scientific) problems to understanding texts or persons. Tacit knowing is seen to consist in relying on integrated and interiorized particulars for attending to the comprehensive entity on which these particulars bear, and in terms of which they are (tacitly) known. Accordingly, a formal definition of tacit knowledge and its structure may read thus: a person *A* has tacit knowledge of a collection of subsidiary clues *S* if (1) *S* is integrated by *A,* (2) *A* is not directly aware of *S,* and (3) *A* has integrated *S* such that (4) *S* bears on a focal whole, *F.*

On this construal, all knowledge is more or less embodied and either tacit or rooted in tacit knowledge. Moreover, tacit knowledge can be seen as the model of all skillful problem solving, of which scientific discovery is the paradigm case. Inquirers follow rules they can hardly specify and are seldom aware of. In this respect, tacit knowledge is more like knowing how to do things or what things are for than propositional knowledge that something is the case. Near parallels here are Gilbert Ryle's distinction between "knowing how" and "knowing that," and Bertrand Russell's between "knowledge by acquaintance—knowledge by description." Finally, the personal character of tacit knowledge does not make it subjective or irrational. Acquired in the context of social practices of learning and inquiry, it is both personal and social.

The implications of this theory for the dialogue between science and theology are at least the following. First, by emphasizing that contexts of "coming to know" cannot be governed wholly by general rules, the theory would support historical, evolutionary, and cognitive approaches to science and religion, rather than rationalist, metaphysical, and logical ones. Next, by presenting an alternative to impersonal and reductionist accounts of science that focus exclusively on questions of justification or methodology, the theory influenced many theologians, including Thomas F. Torrance, Ian Barbour, Arthur Peacocke, and Lesslie Newbigin. It advocates the personal and fiduciary nature of scientific knowing in practice that is not at odds but consonant with religious understanding. Finally, tacit knowledge as embodied, personal, and social points to a common ground for science and religion, not of a methodological or metaphysical nature, but of an evolutionary, cognitive, and anthropological nature. Permeating all human inquiry—scientific as well as scholarly, aesthetic, moral, and religious—tacit knowledge shows that all claims to know and understand are voiced from within traditions and shaped by values that can only be upheld within a free society that allows people to adhere to them.

See also EPISTEMOLOGY

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ANDY F. SANDERS

TAOISM

See CHINESE RELIGIONS, DAOISM AND SCIENCE IN CHINA

TECHNOLOGY

The definition of *technology* is a much controverted topic. At one extreme, the word is used for an intellectual discipline, analogous to *biology* or *psychology*. This is a refined use, emphasizing the Greek root *logos* (word or meaning) combined with *techne* (artifice), to focus on the study or science of arts and artifices. Thus, distinguished institutions that offer sustained investigation of practical arts are often called institutes of technology. But at the other extreme, the word *technology* is often used to refer to concrete objects, tools, and implements themselves, or their workings. When archaeologists speak of digging up samples of a culture's technology, they are not referring to learned studies but to pots, tools, or weapons. Historians and anthropologists refer to the technologies of a society as the practical arts and implements themselves, not studies about them. And ordinary usage tends also toward the concrete. When one is baffled by the technology in a new car, it is the knobs and switches that are at issue, recalcitrant things.

Another polarity is found regarding the involvement of science in technology. Is technology (whether a study or a set of artifacts) simply applied science? If so, then science must have come first, to be applied, and there could be no prescientific technologies. The distinguished institutes of engineering tend to lean toward this understanding, but historians of human craftsmanship tend to see important continuities between pre- and post-scientific arts, and emphasize vital technological achievements (such as the telescope and microscope) that made science possible, thus predating and empowering the rise of modern science, not shrinking to its mere application.

There are other significant disputes over the essential nature of technology: for example, whether it must be embodied, somehow, perhaps in metal or plastic, or whether it can be entirely conceptual, as in the important Arabic invention of the number zero, which greatly advanced the calculational power of mathematics. Another example is the question whether technology can be said to exist outside the human context, as in the sometimes elaborate constructions of animals like beavers and many birds, or must it by definition be the product of human making? This raises the broader issue whether technology is ever a natural phenomenon or is necessarily artificial. Unfortunately, the relatively new field of philosophy of technology has yet to come to consensus on these definitional issues.

Technology and language

In the absence of consensus, the process of constructing and evaluating a definition is actually clarified. One cannot pretend that a proposed definition is inevitable, or is the only one that stands to reason. It becomes more obvious that language is conventional, that a definition is a rule for linking concepts together in ways that are clarifying or helpful. Since what is clarifying or helpful is always relative to some context-giving purpose, there may be as many differently helpful resolutions for using words as there are purposes for doing so. Deans of distinguished institutions for the systematic study of industrial arts may find it helpful to use words in one way; aircraft maintenance personnel may find it more helpful to use them in another.

Since the purpose in this entry is philosophical, its aim will be for as much comprehensiveness as reasonably possible, combined with as much critical coherence as can be achieved in light of the variety of data in hand. The norm of adequate comprehensiveness will warn against premature exclusions of whole domains from the extension of the term under discussion, and the norm of critical coherence will warn against such excesses of inclusion as might make the term vacuous by referring uncritically to everything. For example, if we are to understand technology from the broad philosophical perspective, it will probably be more useful to include prescientific craft traditions within the concept of technology, to see the internal similarities and differences brought by modern science, than to exclude the earlier practical arts from notice by definition. But, contrariwise, since understanding a subject must allow for contrast with what is not that subject, it will probably not be useful to accede to such all-inclusive definitions as would identify the mind-activated body as the primary all-purpose tool. This would imply that a conscious human being is never without tools, is never in a nontechnological condition. With an over-broad definition it is harder to express the significant difference that the introduction of a tool makes to the naked hand; with an over-narrow definition it is harder to notice significant similarities between tools of different types.

Venturing our own definition, in this context, must be an exercise in balance. We must be conscious of what we will include and what exclude by our proposed linguistic rule, and must be ready to stand by these consequences as long as we support the rule. For example, the concept of the *practical* has been central in all the discussion thus far. If we make this concept essential, then we exclude from the concept of technology what is purely theoretical or aesthetic or otherwise done for its own sake, without practical motives. If this seems appropriate, we are entitled to make this decision. Again, the concept of the *purposive* runs throughout, implying *intelligent goals* as essential to the idea of technology. If this cluster of concepts is taken as essential, then we shall be excluding the purely instinctive from our definition. This need not eliminate a priori all animal constructive activities from the domain of the technological, but it draws the line at a new place: To what extent are the apparent artifacts of animals actually the result of art, or intelligence? If the human species is not alone intelligent, then the concept of technology will apply quite naturally to flexible, environmentally responsive implementations of animal aims, but will not apply to behaviors that are hard-wired, immune to modification in changing conditions. Is this an appropriate distinction? If so, we may legitimately adopt it. Finally, the concept of *physical embodiment* remains to be resolved, whether technology must necessarily be *implemented* in material things. If we so decide, then purely conceptual discoveries or inventions, like the Arabic zero, will be excluded from the technological, while the abacus, another great aid to calculation, implemented variously by pebbles in sand or beads on wires, will be included. Like all the other decisions, this is a judgment call. Will it be more helpful for understanding technology to require that it be *implemented,* especially if that requirement can be understood to include not just metal or plastic but also social and biological implementations, as in the invention of armies and corporations or in the selective breeding of new strains of grain or livestock? If the answer is positive, then this resolution may reasonably be made.

Thus, once we are alert to the conceptual consequences, and accept them, a possible definition of technology, one that could reconcile a number of clashing linguistic intuitions and lay a foundation for further clarifications in this important domain, could be: Technology is the practical implementation of intelligence.

Technology and science

Approaching technology as implemented intelligence aimed at practical goals helps to resolve the contentious question of its relationship to science. There is no doubt that the character of technologies changed radically after the emergence of modern science. There is also no doubt that prescientific technologies, such as the art of lens making and glass-blowing, were indispensable to that emergence, since without them there would have been no telescopes, microscopes, thermometers, or barometers to serve the new goals of precise theoretical intelligence represented by the scientific revolution.

But the differences between the type of intelligence embodied in ancient craft technologies and in modern high technologies are not in kind but in goals and norms. Practical intelligence, as old as our species, is interested in getting jobs done and clinging to techniques that have been found (usually by luck, or trial and error) to work. The norm for such intelligence is practical success, with deep reluctance to fix what is not broken. Simplicity is preferred over complication, the how is elevated over the why, and close enough is favored over abstract precision. In contrast, theoretical intelligence (rooted in the same ancient quest that sometimes leads to myth-making and sometimes, as in classical Greece, is disciplined by logic) thirsts for understanding why, is not satisfied by successful results alone but wants to know in addition what makes things happen so, and is willing to take great pains to achieve precision despite whatever complexity is required. These two contrasting expressions of intelligence, usually isolated by socioeconomic class, made an improbable marriage in seventeenth century Europe, through which the demand for theoretical precision could be served by instruments provided by ancient craft traditions, and the quest for why could be disciplined by attention to the how.

For the first time, practical wants could be suggested by theoretical understanding of the hidden workings of things. The radio could not even be desired without first conceiving abstractly of radio waves. Atomic energy could not be a goal without the modern theory of the atom. After the emergence of modern science, so-called high technologies could be led by theoretical intelligence powerfully outfitted by practical intelligence.

Technology and culture. Technology is the implementation not only of intelligence in various interacting modes but also equally of values, goals, wants, and fears. Without motivating values, intelligence would not be moved to make or do anything. But in culture, values often clash. Early biblical pessimism about technological hubris is shown in the story of the Tower of Babel (Gen. 11: 1–9), foreshadowing modern negative theological and philosophical attitudes such as those expressed by Jacques Ellul and Martin Heidegger. Science-led high technologies stimulate even stronger condemnation from those suspicious of the practical implementations of human intelligence, but the involvement of modern science is not essential to setting off warnings. Agricultural technology, and urban living itself, is seen as corrupting by the nomadic and sheepherding author, called J, in early biblical thought.

More positive theological assessments, ranging from Harvey Cox's early enthusiastic embrace of the liberating technologies of the secular city to W. Norris Clarke's more measured approval of human co-creation through selective technology, also abound in the literature. Philosophers and social commentators like Herbert Marcuse, Erich Fromm, and Bernard Gendron defend in different ways the technological impulse and its impacts on culture.

The technological impulse, to intervene intelligently in nature by implementing means for achieving valued ends, is extremely general, however, and open to indefinitely many expressions. The qualities of the intelligence being implemented, as well as the values being embodied, are worthy of analysis and assessment epistemologically no less than ethically and theologically. Though the activities of intelligence may bind all sorts of technologies into a single wide domain, its implemented expressions through modern science are strikingly different in standards and consequences from its prescientific embodiments. Artificiality comes in many degrees, depending on the extent to which the artificial object is dependent on the intervention of intelligence for its production. A neatly planted orchard, for example, is more artificial than a primal forest, but less artificial than the shopping mall that may replace it. On such a scale, modern high technology is artificial to the highest degree because it is completely dependent on the intervention of theoretical intelligence for its existence. Some of the felt discomfort directed toward such technologies may be rooted in the cognitive gap between ordinary experience of the world, familiar to our species from earliest times, and the theoretical structures inhabited by scientific intelligence and materialized in scientific engineering.

Importantly, too, the internal goals of scientific intelligence tend to favor quantification. Much science-led technology may not surprisingly, then, embody the tendency to favor quantity over more ineffable qualities, such as the aesthetic or traditional. Further, scientific values, though powerful in advancing knowledge, are conspicuously lacking in compassion for its subjects of investigation. The typical technological implementations of scientific thought, with some exceptions (e.g., anesthesia) have not been especially kind or gentle. We may speculate that if we are to hope for a kinder, gentler postmodern variety of high technology, sensitive to qualitative concerns in culture, there may need to rise a new, postmodern variety of scientific thinking as well.

See also BIOTECHNOLOGY; INFORMATION TECHNOLOGY; REPRODUCTIVE TECHNOLOGY; TECHNOLOGY AND ETHICS; TECHNOLOGY AND RELIGION; VALUE, SCIENTIFIC

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FREDERICK FERRÉ

TECHNOLOGY AND ETHICS

If the concept of *technology* includes human arts and crafts, generally, not simply the science-led *high technology* of modern times, then the influence of technology precedes the dawn of history itself. This entry assumes the more inclusive sense, taking *implemented intelligent practical purpose* as key to the subject, thus binding both traditional and high technologies into a common domain for ethical assessment.

Ethical assessment itself tends to divide into two great approaches. One tradition looks primarily to the consequences of what is being evaluated. Is an action or policy (or habit or trait of character, etc.) likely to produce good results? If so, on this tradition, the action is ethically right, morally to be approved, because of its consequences. The other tradition focuses primarily on the type of action or policy under consideration, whether it conforms to a rule that defines what is right. If so, the action reflects what is morally to be approved, regardless of its consequences.

It is clear that these approaches to ethical assessment can and often do argue past one another. The first position, here called *outcome-ethics* (also often called *teleological* or *consequentialist* ethics), may declare that policy *P* does no good, while the second position, here called *rule-ethics* (also often called *deontological* ethics), may insist that policy *P* flows inescapably from accepted rule *R.* Both may be correct in what they hold. But if they come to opposing views on the ethical wrongness or rightness of *P,* they have missed each other's point. Rule-ethics is not interested in outcomes but in the principle of the thing; outcome-ethics is impatient with abstract principles, when concrete helps and harms are at stake.

Reconciling ethical methods

Ethical assessment of technology is made still more difficult because of tensions within the approaches themselves. Outcome-ethics is based on maximizing *good,* but differences abound on defining this key term. Pleasure, honor, well-functioning, and so on, are all possible candidates, but different definitions would call for different policies and would cast different ethical light on the technological means for achieving them. Defining the good in terms of honor, for example, might give a positive ethical assessment to the erection of catapults and the casting of cannon, while defining it in terms of pleasure might call for a more negative stance toward the implements of war.

Another difficulty for outcome-ethics, however the good is defined, is in determining when the ethically relevant outcome has come out. Events roll on, and a positive situation (e.g., avoiding the pains of battle) may be supplanted by a negative one (e.g., falling under an oppressive conqueror), which in turn leads endlessly to others. The openness of the future seems to make an ethical verdict on any outcome only provisional.

If the future is a problem for outcome-ethics, so also is the past. Taken literally, the measuring of ethical worth by future outcomes alone seems to leave the past without ethical significance. A promise once made would need continual reevaluation by changing future probabilities. Destructive acts in the past should be punished, if at all, only by reference to future good to be achieved; good deeds, once done, should be rewarded, if at all, only by looking toward future results.

These counterintuitive consequences are escaped by rule-ethics, which does not need a prior concept of good for its concept of right, does not make its ethical judgments hostage to a receding future, and is not required to ignore ethical obligations from the past. But there are analogous equally deep problems for rule-ethics, if taken alone. First, there are many disagreements within this approach as to which rules should rule. Even excluding, in this entry, many conflicting claims of divine commands, profound disagreements may be expected on the source and authority of proffered ethical principles. Do they rise from an innate intuition? From societal enculturation? From a rational imperative? How much weight should these principles, given their sources, command? How general or specific should ethical rules be? The more they are detailed and specific, the more particular circumstances—even outcomes—dominate the rules; the more they are general and abstract, the more ethics loses touch with the concrete particularities of life. Rule-ethics gains much of its power from its principled distance from particular circumstances, but such distance makes it vulnerable to the temptations of fanaticism.

Somehow the clashing approaches to ethical assessment need to be reconciled if past technological decisions are to be adequately evaluated and future policies properly assessed. Technological implements are means to practical purposes. Since means are always aimed at ends, consequences must count in technological ethics. But also, since purposes can be formulated in terms of general motives, norms must also be applicable to technology.

A balance might be struck by acknowledging that concrete outcomes are the matter of ethical concern, while general rules constitute its form. Outcome-ethics could recognize that among alternative outcomes, some might be deeply unfair in their distribution of the good, and these would be worse outcomes than more equitable ones. But fairness is not simply one more addition to the good; it is a principle or rule on how the good should be spread. Cost-benefit analyses of technological outcomes are weak if they ignore the question of who bears the costs and who enjoys the benefits, and whether these are justly proportioned. Further, outcome-ethics needs to consider rights and wrongs of past technological decisions, even if nothing can be done about them any longer. Recognizing mistakes in the past and formulating guidelines to help avoid similar mistakes in the future, is an important ethical activity utilizing norms and principles, not just predictions. In these ways outcome-ethics (in order to do its own chosen job well) needs to learn from rule-ethics.

Reciprocally, rule-ethics needs to learn from outcome-ethics if it is to remain relevant to the fears and hopes that drive technological activity. Consequences do matter ethically to real people. Rules must not be allowed to blind moral concern from seeing concrete pains. Rules need to be responsive. This is especially obvious in the context of high technology, where possibilities of doing things become practical for the first time. When entirely new types of doing are contemplated, existing rule-books may not be adequate for guidance. This does not mean that rules are not relevant. But rules need to be extended, amended, and reviewed in light of novel facts and unprecedented possibilities. Modern technology, with its radical novelties, makes this extension of traditional ethics (both outcome- and rule-ethics) vital.

Examining historical cases

Over the course of human history, the outcomes sought by technological implements reflect every kind of practical good (real, imagined, or perverse) that human beings are capable of craving. Food, shelter, the death of enemies, the docility of slaves, accurate records—a list without end—have been sufficiently valued so that intelligence has been put to work creating artifacts to secure them. For one grisly example, some medieval cities in Europe maintain so-called police museums displaying the technologies of punishments once meted out to malefactors. Cleverly devised implements of torture, including metal seats for roasting, iron claws for tearing, racks for dislocating, were the embodiment of purposeful design in quest of something taken by many in that society as a public good. We may shudder today at these artifacts, and question whether those goals of inflicting extreme pain were really good, or whether the larger good of public order really required such measures, just as it is possible to shudder and ask the same questions about the practical intelligence and values embodied in our publicly approved electric chairs, gas chambers, and paraphernalia of lethal injection. Here we encounter the appropriate critical task of technological ethics. Using the methods of outcome-ethics, one needs to examine whether the consequences sought can really be approved as good over the longest anticipated time horizon, and if so, whether in fact the means proposed are the best ones for achieving these critically examined results. At the same time, using the methods of rule-ethics, one must ask whether the principle of fairness is being served in distributing the various goods and ills concerned, whether the type of action contemplated falls under clearly stated and approved principles, whether these specific principles can be further justified by a hierarchical order of still more general norms, and whether this more comprehensive set of interlocking norms itself is clear, consistent, adequate to the larger circumstances, and coherently defensible to a thoughtful, unbiased judge.

A famous rejection of industrial technology occurred in the early nineteenth century in northern England, when the Luddites, followers of a (possibly mythical) Ned Ludd—purportedly a home weaver displaced by new factory-based machines—smashed the power looms that threatened their ways of life. It is likely that this direct action was motivated more by economic than ethical values, and it was put down by gunfire and hangings, but many ethical issues are raised. What were the ethically relevant consequences of the shift from home industry to the factory system? One consequence was greatly increased volume of production, a prima facie good. Another was the replacement of a society of small producers, owners of their own looms, with a laboring class, required to sell their services to others who owned the means of production. This outcome is prima facie negative, involving a decrease of dignity, loss of cohesion in family life, and a corresponding increase in alienation and insecurity. The factory system, and eventually the assembly line, produce mixed consequences. Ethical examination needs to sort these out, and weigh them. In terms of principle, as well, there are profound issues of involuntary social change forced by technological efficiencies. To what extent should the autonomy of persons to choose their basic conditions of life be honored above the promise of greater economic productivity? On whom will the burdens fall when technology uproots life? Will those who bear these burdens receive a fair share of the new rewards, or will these flow disproportionately to others?

Should society provide institutional opportunities for all the people involved to discuss and decide these ethically vital questions? Can any society that fails to do so consider itself genuinely democratic?

These questions reveal a serious general problem in technological ethics: the arrival of many revolutionary changes as faits accompli. Well before the appearance of high technologies, simple trial-and-error discoveries deeply altered valued conditions of life before they could be prevented or even discussed. Alfred Nobel (1833–1896) was keenly aware of how much his invention of dynamite would shake the world. The invention itself, in 1867, was wholly in the craft-tradition, a chance discovery that nitroglycerine could be absorbed by a certain porous siliceous earth and thus be made much safer to use. Various types of dynamite were used in blasting tunnels and mines, as well as in cutting canals, and building railbeds and roads. The consequences of these applications deserve analysis as ethically quite mixed, socially and environmentally, but of course the most spectacular use of the high explosives stemming from Nobel's invention was in war. Nobel himself established his prizes, including the Peace Prize, to coax the world toward better outcomes. He even dared to hope that the power of dynamite would make future wars unthinkable. In this he was sadly mistaken.

Assessing contemporary challenges

The leap from chemical high explosives to high nuclear technology may on the surface seem short, but in fact it represents a qualitative change. The high explosives of the nineteenth century were grounded in the same tradition of craft advancement that had characterized human technique from prehistoric times. A lucky empirical discovery was noted, remembered, repeated, applied, extended, and exploited—a paradigm instance of excellent practical reasoning. The atom bomb, in contrast, had to await a spectacular achievement in theoretical reasoning about nature even to be conceived. Specifically, a revolutionary change in understanding the relationship between matter and energy, wrought in the mathematical imagination of Albert Einstein (1879–1955), and stated in his famous energy-mass equation, $E = mc^2$, was a necessary condition for even recognizing the phenomenon of nuclear fission energy release when it occurred in German laboratories in 1938, and certainly also for seeking fission energy as a practical goal. Einstein himself was skeptical of this practical possibility, when first alerted to it in 1939 by Niels Bohr (1885–1962), but he was soon convinced by further experiments conducted immediately for him at Columbia University. Later in the same year, Einstein signed a letter to President Franklin D. Roosevelt alerting him to the danger of allowing German scientists to be first in unlocking the huge energies predicted by his theory. From this warning sprang the Manhattan Project, at that date the largest science-led technological project ever launched. The ethical ambiguities of the atom bomb, its use in the war against Japan and its role in deterring a third world war in the twentieth century, have been much discussed. Conflicting estimates of the consequences for good or ill, conflicting identification of the relevant ethical principles involved, are well known. Although of a new type, as offspring of theoretical intelligence, and of new scales in magnitude and urgency, nuclear bomb-making is subject to all the old ethical concerns.

What adds a special challenge for ethical assessment after the rise of theory-led technology is a new responsibility of assessing major technological innovations after they are conceived in principle but before they are born in practice. Technology policy can be ethically deliberated. Two examples will serve to illustrate.

Shifting from nuclear fission to fusion, we may assess the still-unrealized technology of electrical energy production by controlled thermonuclear reaction. In 1939, the hitherto mysterious source of the sun's prodigious energy output began to be understood theoretically as coming from energy released in a process by which four hydrogen nuclei are joined, when enormously high pressures and temperatures overcome electrical charge repulsion, thus forming one helium nucleus. This source is quite different in principle from the nuclear energies released when a heavy nucleus, such as the isotope uranium-235, splits into lighter nuclei. The two distinct processes are spectacularly combined in thermonuclear (so-called hydrogen) bombs, when the enormous but uncontrolled heat and pressure of a fission reaction forms the momentary star-like environment in which heavy hydrogen isotopes deuterium and tritium are forced to fuse into helium.

The theoretical lure to create useful electrical energy from a controlled fusion process is strong. The fuel, primarily deuterium, is plentiful, widely distributed, and relatively cheap. Every eight gallons of ordinary water contains about one gram of deuterium, which in principle could provide as much energy as 2,500 gallons of gasoline. There is no radioactive waste to guard or dispose. The practical difficulties, however, are extreme. The main technical problem is containing the unimaginably hot plasma of nuclei so tightly that a sustained reaction can occur. No material container could be used without instant vaporization. Strong magnets need to hold the writhing plasma away from all objects while a net surplus of energy is somehow extracted. Intense efforts have been under way for decades; perhaps someday the theoretical possibilities will be actualized.

But should fusion energy be practically realized? Ethical questions remain open for debate. Many positive outcomes are promised. Human society might be freed from dependence on oil, natural gas, and coal, with positive economic and environmental consequences. The rule of fairness in distribution of the fuel itself is better met, since water is a more widely available resource than oil or coal. Distribution of devices for deuterium extraction and of expensive fusion reactors would of course need scrutiny for fairness. One seldom considered question is whether human beings, in principle, should be freed of all need to deliberate and choose between energy expenditures. Has our species earned the right to be trusted with the capacity to pave over the world? This worrisome question forces attention again to the complexity of the long-term consequences that could reasonably be expected. The ethical debates have hardly begun.

The ethical debates over our second example, the technology of cloning, exploded into public consciousness with the appearance of Dolly, a cloned sheep, in 1997. Significantly, this is a technology led by theoretical biology, not to be confused with the techniques of selective breeding, which are as old as agriculture itself. Cloning technology is made possible by the revolution in understanding organic life brought about by the science of molecular biology, and especially by DNA analysis in genetics. Dolly's type of cloning, long believed to be impossible, depends on replacing the nuclear DNA in an egg cell with the nuclear DNA from an adult somatic cell of another organism. The donor cells are made quiescent by starvation, after which the donated DNA from those cells is fused into the host egg cells by electrical pulses, and the activated eggs, after a short period of in vitro development, are implanted into a womb.

Ethical assessment of various types of cloning in agricultural application, where the production of sheep, cattle, and pigs is concerned, is likely to dwell on outcomes more than rules, though there are significant voices calling for a moratorium or prohibition, in principle, against so-called Frankenfoods, because of their unnatural origin, or perhaps because of offense taken by the possibility of transgenic manipulation of genetic characteristics. Ethical consideration of consequences will point to the increased good of more and better quality food in a hungry world, while opponents will urge the possible dangers to health, both of consumers and of over-manipulated organisms designed too narrowly by genetic engineers focused exclusively on the dinner table. A great deal more information is needed on these hopes and fears. Meanwhile, the principle of informed consent may be important in the marketing of artificial life-forms, so that consumers are given full information about what they buy and eat.

Still more intense passions rise in ethical debates on the possible cloning of human beings. Here appeals to rules tend to come first, though ethical concerns about consequences are also important. Aside from religious objections, ethical principles concerned with the uniqueness and dignity of human individuals may be invoked. Certainly, in principle, no human person should be cloned merely to serve as an organ bank, to provide rejection-free transplants for an ailing heart, for example. But might cloning be allowed from a dying child's tissues to alleviate an aching heart, if this could provide a DNA-identical replacement to nurture and love? Although all might agree with the rule that no person (including clones) should be treated as nothing but a means, might there be legitimate mixed situations, where a clone could be valued primarily as an end but also to some degree as a means?

Factual outcomes need close attention here, as well. If the motive is to produce mere replicas of specific persons (musicians, athletes, soldiers, scientists, perished loved ones, etc.), this may be both objectionable in principle and also unachievable as an outcome. Cloning will never be able to replicate persons exactly. Persons, within general genetic limits, are partially self-creating beings. Monozygotic twins (or triplets, etc.) are not really identical persons, despite shared DNA and largely similar in utero and childhood conditions. Much greater differences of environmental conditions, in the womb and throughout life, will assure that even the identical DNA shared by donor and clone will not violate the latter's uniqueness of personhood. Ethical evaluation of this luring and horrifying possible technology, like many other technologies still aborning, needs to become more subtle in analyzing principles and anticipating outcomes.

See also CLONING; INFORMATION TECHNOLOGY; BIOTECHNOLOGY; REPRODUCTIVE TECHNOLOGY; TECHNOLOGY; TECHNOLOGY AND RELIGION

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FREDERICK FERRÉ

TECHNOLOGY AND RELIGION

Technology, understood as *practical implementation of intelligence,* is a matter of know-how expressing values. Thus technology must somehow relate to religion, positively, negatively, or neutrally, since religion is also supremely a matter of values and ideas. Values come first for both, though ideas—strongly valued ones—will always be importantly present in both domains as long as *Homo sapiens* is a thinking species.

Religions are differentiated by a conflicting plethora of symbols and beliefs, but are alike functionally in expressing worship. *Worship* is here understood as directed to what is taken to be of first importance (last to be sacrificed) and of widest relevance (impossible to be marginalized). Thus *religion,* in principle, is our most intense and comprehensive way of valuing. This is a highly abstract characterization of religion. Actual people, on this understanding, are more or less concretely religious; some, who are casual about their values and see nothing as of comprehensive importance, may hardly be religious at all. Religious institutions, made up of actual people, are also more or less religious, since admixtures of economics, politics, cultural tradition, and the like, may be expected in every major human context.

Asian religions and technology

Divergent intuitions divide the primary world religions over what is ultimately worthy of worship, and thereby influence attitudes toward technology. Hinduism, in its Vedic and Brahmanistic forms, focuses its ultimate valuations on *brahman,* the transcendent, impersonal principle of universal order, paradoxically identified with *atman,* the individual soul. Although intermediate castes include warriors, producers, and servers, all of whom might take an interest in worldly technology, the most intense and comprehensive valuations of this many-stranded religious tradition focus on the priestly caste's ultimate goal of renunciation—the termination of an otherwise endless round of birth, death, and rebirth. Implements expressing practical intelligence for uses in this world, therefore, are of little religious significance. The predominant stance of Hinduism toward technology is neutrality, bordering on indifference.

Buddhism, Hinduism's offspring religion, takes a similar posture, though with a more pronounced negative tilt. Buddhism, because of its enormous variety and complexity, as cultural form and philosophy as well as religion, resists most generalizations. But the Four Noble Truths, traditionally traced to the Buddha's first sermon following his enlightenment, are as fundamental to all versions as can be found. The First Noble Truth diagnoses the basic human condition as suffering (*duhkha*), while the Second identifies craving or desire (*tanha*) as the cause of this suffering. The Third Noble Truth affirms that suffering can cease with the cessation of craving, for which the Fourth prescribes an Eightfold Path (right view, right thought, right speech, etc.) as the cure. But since technology, as intelligence seeking practical goals, is fundamentally powered by a desire or craving for something either to be achieved or prevented, it is hard to imagine an honored place for it if craving itself is the primary enemy. True, Buddhism steers for a middle way between the extremes of asceticism and hedonism, and would not advocate a brutish life, devoid of tools. But since Buddhism's oldest, highest value is the state of nothingness, transcending desire as such (that is, the state of *nirvana,* where all craving and all suffering have completely vanished), we would look in vain to Buddhism for religious guidance on technology policy.

Confucian thought is far more practical. Its emphasis on the sage of virtue, properly hierarchical society, and correct ceremonial practices, in order to retain both balance and the blessings of heaven, is emphatically this-worldly. However, its strong emphasis on the rectitude of the ruler and on virtues proper to the sage tended to deflect concern from the humbler manual arts. Chinese technology, for all its ingenuity, developed in relative isolation from religious attention—assuming, as we do, that Confucianism qualifies as a religious phenomenon, despite its secular and humanistic spirit. This spirit expressed for its adherents what, in the widest possible context, is most to be valued.

Daoism represents another religious tradition, but one with which Confucianism was able to coexist for millennia. It is said that in the late sixth century B.C.E., Confucius visited Laozi, the Daoist philosopher, to consult him on ceremonies, adopting the role of disciple. At any rate, the cosmic balance sought in Daoism is compatible in many ways with Confucian ideals. The metaphysical scale, however, is much grander in early Daoism, formulated in the *Dao de jing* (or *Tao-te ching;* attributed to Laozi), in which the Dao (or Way) is identified as a featureless, eternal, primordial reality, the mother of the world, giving birth to all things. Unity, above all, is to be sought, with the masculine principle (*yang*) requiring completion and balance with the feminine principle (*yin*). Everything, metals, geographical directions, seasons, colors, and so on, could be classified in terms of these oppositions in need of harmonization, calling for a yin-yang way of life beginning with attention to one's own bodily health. To Daoism's metaphysical enlargement is added a mystical spirit strongly contrasting with Confucian worldliness. Unity is so important that it drives out the possibility of discursive thought, which inevitably breaks up into multiplicity of ideas. Similarly, the Daoist sage, unlike the Confucian, is warned against intervening in the course of events. This policy, called *wu-wei,* is not one of absolute inactivity, but stresses the importance of respect for the autonomy of other happenings, both in their independence from the self but also in their complete relatedness to the network of things and processes as a whole.

Through disciplined nonaction the Daoist relates to the eternal Dao, finding increased personal longevity and mystic ecstacy as reward. Technology, as we know it, however, has no place within the spirituality of *wu-wei.* Indeed, in our short survey of the primary religious traditions of Asia, we have found none with a positive place for the technological in general.

Biblical religions and technology

The three great religions of the Book, Judaism, Christianity, and Islam, all have mixed records regarding technology. There are characteristic differences between them, but even greater differences between strands internal to each faith.

Judaism, as the oldest, contains within its early scriptures the fundamental tensions felt within all three of the religions rooted in the Hebrew Bible. At the outset, the created world is pronounced good (*Gen.* 1:31). The sun, the moon, the stars, the birds and beasts, the trees and Earth, are all realities, neither indifferent illusion nor tricky *Maya,* and they are of genuine importance. They are not as important as the creator, of course, but they are divinely approved. They are given their names by the first man, and they are handed into permanent human care. Adam and Eve, as exemplary humanity, are from the start commanded to till and keep the garden entrusted to them (*Gen.* 2:15). Even after expulsion from the initial paradise, humanity must continue to till the ground, though in consequence of the great disobedience that led to this expulsion, tilling would henceforth involve toil and sweat (*Gen.* 3: 17–19).

In the ensuing world of mixed morality, God not only commissioned and approved the first recorded technological project (*Gen.* 6: 14–16) but also provided the design (three hundred cubits long, three internal decks, etc.) and the specifications (gopher wood and pitch). This was for the great ark that Noah was commanded to build in order to preserve a basic breeding stock to repopulate the world after God's impending flood. There is no hint of disapproval here of tools or the practical arts in general. On the contrary, human construction is a pious act and is rewarded with survival. But immediately following the story of Noah, after the human race has had a chance to replenish itself and spread once more, the descendants of Noah are depicted as offending God by their technological hubris (*Gen.* 11: 1–9). Having only one language, they are capable of unlimited engineering ambitions and decide to construct an enormous tower, reaching all the way to heaven. Before they can succeed in such blasphemy, God says: "Behold, they are one people, and they have all one language; and this is only the beginning of what they will do; and nothing that they propose to do will now be impossible for them. Come, let us go down, and there confuse their language, that they may not understand one another's speech" (*Gen.* 11: 6–7, RSV). In the ensuing linguistic confusion, attempts to complete the tower of Babel are aborted. God clearly disapproves when technological pride oversteps its limits.

This duality in attitude continues to express itself in different strands of Christianity. The mystical, otherworldly side, often (but not exclusively) associated with the Eastern Church, centered in Constantinople, noteworthy for its iconography and other sacred arts, has characteristically distanced itself from the secular crafts. In contrast, the Western, European, side of Christian faith, initially centered in Rome, contains (though itself internally mixed) craft-affirming strands that have blessed technological dynamism in principle and eventually encouraged the emergence of the world of science and high technology. Those monasteries following the Rule of Saint Benedict (c. 480–547) were particularly significant for maintaining a sanctified balance between prayer, reading (or copying) scripture, and practical work, including labor in the gardens and fields and devoted craftsmanship of many kinds.

Islamic religion inherited what Christians call both the Old and the New Testaments, in addition to its own Qur'an and prophetic writings. Not surprisingly, the relationship between Muslim faith and technological prowess shows the same ambivalence we have noted in the other two Biblical religions. One of the technological domains enthusiastically entered by early Islamic culture was architecture. Islam requires frequent centralized meetings of the faithful, but existing structures were seldom adequate. The earliest practice of meeting in private houses was quickly outgrown, as Arab conquest spread Islam during the seventh and eighth centuries. Existing synagogues and churches were also usually unsuitable for mosques, which were used not simply as places of worship but also as community centers. In response, the hypostyle mosque, a rectangular building of many columns supporting a roof, was invented, allowing easy expansion by the addition of columns in the event of community growth. Minarets, initially built only in non-Muslim cities as prominent vantages for calls to prayer, were also created. But, simultaneously, decoration of Muslim artifacts was tightly restricted. Fierce rejection of even a hint of idolatry in this ardently theocentric religion strongly opposes the representation of living forms, lest human creativity usurp the exclusive prerogatives of the sole Creator. Iconoclasm, familiar in Jewish prohibitions on graven imagery and appearing at least sporadically among Christians, is a powerful governor in Muslim attitudes toward arts and crafts.

Historical development

Not surprisingly, the religious background of a culture makes a large difference in its characteristic readiness to respond to or incorporate technologies, as such possibilities present themselves. In Tibet, deeply steeped in classical Buddhist thought and perception, for example, the *Manichos 'khor,* or prayer wheel, a mechanical device consisting of a hollow metal cylinder containing a written mantra, has been in use for centuries. Each revolution of the cylinder is thought equal to one oral recitation of the mantra. From ancient times, these prayer wheels have been attached to windmill or waterwheel devices that have served to multiply prayers without human attention or effort. But, significantly, the harnessing of wind or water power did not extend to grinding grain or sawing lumber.

Western European attitudes, set in a branch of Christianity generally favoring the biblical affirmation of the importance of creation under human dominion, were far more ready to accept technological innovation. Monks, squinting over their copy work, were quick to accept the benefits of eyeglasses, when glassblowing crafts made lenses possible. The Christian peasants of northern Europe, perhaps as early as the seventh century, invented the moldboard plow to cut deeply into and turn the soil, rather than settle for Near Eastern and southern Mediterranean plows—suited to lighter soils—that merely scratched the surface and required cross plowing. The historian, Lynn White, Jr., comments in "The Historical Roots of Our Ecologic Crisis" (1967): "Formerly, man had been part of nature; now he was the exploiter of nature. Nowhere else in the world did farmers develop any analogous agricultural implement. Is it coincidence that modern technology, with its ruthlessness toward nature, has so largely been produced by descendants of these peasants of Northern Europe?" (p. 1205).

Countless other technologies were grasped and put to practical work by the Western Europeans, with encouragement from its dominant religion. The magnetic compass freed seamen from hugging the coasts, making European exploration (and ultimately domination) of the rest of the world practical. The voyages of Christopher Columbus and other explorers were enthusiastically supported by Church interests, and it is no coincidence that missionary priests accompanied him and other openers of the New World.

In the twentieth century, the technologies of urbanization and modernization were subjects of theological celebration by at least some Christians. In *The Secular City* (1966), Harvey Cox praised what he called the disenchantment of nature, the elimination of its ghostly terrors, at first permitted in biblical religions by the concentration of all sacredness in the creator, excluding everything created, and then at last achieved by the antiseptic powers of modern science. He also welcomed the desacralization of politics and the freedoms of anonymity provided by technological society.

In sharp contrast, reminding us of the deep ambivalence of the biblical religions toward technology, particularly technologies suggesting hubris or idolatry, many theological voices were raised in opposition to the atomic bomb during the twentieth century. A particularly forceful voice was that of Jacques Ellul, whose indictment of nuclear energy included not only the bomb, but also the megalomania of atomic power generation in general, and of the heedless science that makes it all possible. In a 1974 essay called "*Le Rapport de l'Homme à la Création Selon la Bible*" ("The Relationship between Man and Creation in the Bible"), Ellul summarizes: "The effort to affirm science by itself, without limit, as judge of everything and carrying its own legitimization *inevitably* involved, as the other side of the coin, the devastation of the world, the squandering of possibilities, the frenzy of destruction" (p. 153).

Contemporary challenges

Most great religions have traditional ways of dealing with such apocalyptic anticipations, and even short of apocalypse, religions have (alas) had much experience with mayhem and devastation. Standard theological responses, even when the scale of devastation is very great, may be expected. A great fire is a great fire whether caused by burning pitch, chemical explosives, or nuclear fission. What is radically new, however, is the empowerment provided by science-led (or *high*) technologies to accomplish hitherto inconceivable ends.

For one major example, theoretical biology has inspired mapping the molecular basis for the complete array of genes in the cells of a human person. This could never have been so much as an objective, apart from the theoretical work leading to the understanding of the double helix of DNA codons that constitute the alphabet spelling out all living organisms. Now that the Human Genome Project has succeeded, and genetic engineering is an established technology, unprecedented practical possibilities are opened for exploitation. New powers of diagnosis of such feared diseases as Tay-Sachs, Huntington's, cystic fibrosis, and muscular dystrophy, are in human hands. Diagnosis is not cure, but genetic engineering promises the synthesis of new medical helps, such as interferon, to increase resistance to viruses. Direct somatic gene therapy is another entirely new possibility, stirring the hopes of sufferers from otherwise incurable conditions such as Huntington's disease. And, beyond curing individuals, the way is opening to modification of the their offspring, and their offspring's offspring, by engineering the germline itself to eliminate unwanted genetic conditions, either in sperm or egg, and either before conception or in the fertilized egg.

Finding adequate religious responses to these, and vastly many other, completely new human powers is the primary challenge for the future. For religions depending upon ancient scriptures to provide divine commands, there is the challenge to avoid objectionable eisegesis and special pleading when clear textual guidance is simply lacking. There is a similar challenge to avoid the common fallacy of begging the question against a technological novelty by (correctly) identifying the new as *artificial,* therefore (correctly) as *unnatural,* and therefore (fallaciously) as *wrong*. Simply to be artificial, the partial product of art or intelligence (and to that extent unnatural), is not necessarily to be illicit. All major religions have come to terms with the interventions of human intelligence and practical purpose in ways that alter nature. Some, like agriculture, are universally recognized as licit. Eyeglasses and hearing aids are also in this inoffensive sense unnatural. The challenge for religious thinking in radically novel cases is to wrestle with what, specifically, it is about practical interventions led by theoretical intelligence—from in vitro fertilization to germ line therapy or even cloning—that makes them unnatural in a bad sense.

Such careful thinking, in order to be relevant and responsible, will need to become well informed about the sciences that lead new high technologies to conceive their novel technological possibilities. In this lies still another challenge for the future relations of technology and religion, since the values and belief-systems of the great religions have not hitherto been forced to take serious account of the values and belief-system of the modern sciences. Modern science has made thinkable, and modern technology has made practical, many gadgets that have been used for religious purposes inimical to the values and beliefs of science. A prime example is the use of electronic tape recorders by the Ayatolla Ruhollah Khomeini (1900–1989) in sending his fiery sermons of Islamic fundamentalism from his home in Paris, rousing the Iranian populace to overthrow Mohammad Reza Shah Pahlavi in 1979. Neither the scientific understanding of the electromagnetic universe, nor the scientific methods and values that made this technology possible, is compatible with the content of those sermons or with the methods and values they espoused. But it is likely that using technologies without appreciating their intellectual and valuational foundations (especially if high technologies are to be manufactured worldwide) will become increasingly difficult. Perhaps gradually, over the current millennium, if religious leaders are forced increasingly to think deeply about the unprecedented technological possibilities being opened to their followers by the practical embodiments of scientific theory, there may be an increased coming to terms with the beliefs and values of science itself.

Such a global coming to terms would require wrenching reforms but not necessarily the abandonment of essential symbols in the great religions of the world. Though it has not been easy, many Christians since Galileo have found ways of accommodating their defining beliefs to established science, and it is not impossible to conceive a similar process globally, spurred by the spread of high technology with its implicit scientific content. If this should occur, a new basis for interfaith ecumenical dialogue might gradually emerge, as well. Such a dialogue could be accelerated by common concerns shared by the great religions for global justice among persons and for the protection of our vulnerable planet against technological hubris.

See also BIOTECHNOLOGY; BUDDHISM; CHINESE RELIGIONS, CONFUCIANISM AND SCIENCE IN CHINA; CHINESE RELIGIONS, DAOISM AND SCIENCE IN CHINA; EINSTEIN, ALBERT; HINDUISM; HUMAN GENOME PROJECT; INFORMATION TECHNOLOGY; ISLAM; JUDAISM; REPRODUCTIVE TECHNOLOGY; TECHNOLOGY; TECHNOLOGY AND ETHICS; VALUE, SCIENTIFIC

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FREDERICK FERRÉ

TEILHARD DE CHARDIN, PIERRE

The thought and works of Pierre Teilhard de Chardin represent the widest and deepest attempt to reconcile Christian theology and the scientific worldview of biological evolution. Teilhard de Chardin noted the peculiar contributions of modern science to the vision of creation. Arguing that evolution moves toward complexity and consciousness, he noted that the order implied by creation is in the future and is achieved as a result of both the mechanisms of evolution and the action of humankind. The theological vision of the movement of creation toward unity, redemption, and salvation is now referred to as the evolutionary universe.

Early life and influences

Pierre Teilhard de Chardin was born in Sacernat in the French region of Auvergne in 1881, a year before the death of Charles Darwin. Teilhard died in New York in 1955. He entered the Society of Jesus in 1899 and was ordained a Roman Catholic priest in 1911. A year later he started his scientific training in natural science with a special interest in paleontology at the Institute of Human Paleontology in Paris, under the direction of Marcellin Boule, one of the most eminent human paleontologists of that time. There Teilhard completed all his scientific training until the doctoral thesis.

Teilhard de Chardin's vocation became clear to him during the first world war; he wrote in his diary: "I would like to reconcile with God what is good in the modern world—its scientific intuitions, its social desires, it proper criticisms" (*Journal,* pp. 90–91). For Teilhard, one of the great novelties of the modern world was evolution: the theory that life, Earth, and the whole universe are subject to a nonreversible change over time. From his point of view, evolution was not only a theory to be investigated, but also the scientific description of a peculiar way of creation, which required new approaches from theologians and philosophers "The adoption of the evolutionary mode for the formation of the world implies a particular mode of appareance 'ex nihilo subjecti' and suggests that this world has a deep *ontological reason*" (*Journal,* p. 264).

After completing his doctoral degree, Teilhard became chair of geology at the Catholic Institute of Paris. There, together with the French philosopher Edouard LeRoy and the Soviet geochemist Vladimir Vernadskij, he coined the word *Noosphere,* which he defined as the totality of all thinking creatures, "the psychically reflexive human surface." According to Karl and Nicole Schmitz Moormann in *Pierre Teilhard de Chardin, L'oeuvre Scientifique,* Teilhard also started to envision a new global approach to evolution as a matter concerning the whole biosphere.

Darwin and evolution

In the meantime, he wrote a private note on original sin, in which he suggested that, in an evolving universe, order is not to be found at the beginning, only to be ruined by human sin, but order will come in the future and has to be constructed by human action. According to Teilhard, there is no gap in the history of life, no nature uncorrupted before sin and corrupted after sin. The mechanism of biological evolution, which involves the undeterministic and dramatic events first elucidated by Darwin, are present from the very beginning of life and are a general characteristic of the evolution of the universe.

Teilhard's unconventional views resulted in his removal from his academic chair and his invitation to stay in China. Yet his theological revolution was only beginning. Because the promise of order resides in the future, he speculated, Christians are not only asked to reach their own eschatological salvation in paradise, but also to construct the Earth and a new type of human on Earth. At the end of the process of evolution humankind will reach a single point of convergence, the Omega Point, where there will be the second and final coming of Christ. A new ontological value is suggested in this scientific description of nature: evolution as movement toward an endpoint, a goal. The deep meanings of the universe, from both the theological and philosophical points of view, are related to this idea of movement toward something: of matter toward life, of life toward consciousness, of consciousness toward the thinking creature and the Noosphere, the Noosphere toward the Omega Point. Teilhard considered this movement the result of the *complexity-consciousness* law and he argued that it recovers the theological necessity for the emergence of humankind.

Teilhard was well aware of new research and discoveries in evolutionary biology. He was most interested in the aspect of Darwinism in which chance plays a central role, but he thought that a correct scientific analysis would be able to demonstrate the presence of *canalisation* (the determination of a direction to evolution in a - particular phyletic branch) and *parallelisms* (phyletic branches that separate off a common branch evolve in parallel and develop similar characteristics). In fact, Teilhard discussed the parallelisms of primates toward increasing brain size in his first scientific papers as a trained palaeontologist. For Teilhard, if there is a general movement that characterizes evolution, this movement has to be evidenced from an experimental point of view. He grappled with the question of how to reconcile this vision with the revision of Darwinism called *modern synthesis,* which was in vogue at the time Teilhard was working in palaeontology and which seemed to deny any epistemological meaning to evolutionary direction.

Teilhard de Chardin believed that only a global experimental approach could demonstrate the directional movement of evolution. Most palaeontologists relied on fossil records, and the lack of a broader global approach by the proponents of the *modern synthesis,* who used a reductionistic approach based on genes and populations, was the epistemological reason for their rejection of the idea of evolution as moving toward a goal. Some of the innovations of biology, for example, the global approach and the definition of biology as the science of complexity, were developed by Teilhard in an attempt to answer questions posed by theology.

Global approach

Central to the evolution of Teilhard's thought was his move to China in 1923, where he worked on the geology, palaeontology, and paleoanthropology of the Asiatic continent. Here, he was able to study evolution on a large scale, both in time and space, and the possibility of a global approach to evolutionary biology became more possible. He intended such a global approach to be part of his program of studying the biosphere, and the continental evolution that he had in mind at the time was an epistemological tool, by which he could study the evolution of the biosphere on a reduced scale but without distortions.

A new model of the interaction of science and theology became apparent: Some of the characteristics of theology, such as the eschatological movement toward an endpoint, and some level of necessity of the thinking creature, are recovered as the metaphysical frame of a true scientific research program. In addition, research that describes the evolution of the universe and its mechanisms can form a starting point for a new theological program. The epistemological model of Teilhard, presented in the introduction of *The Human Phenomenon* (1955), is that there are points where science, philosophy, and theology converge, and these points must be handled in the correct way. The main philosophic frame is that of totality because it is the concept of totality that requires general connections, but totality is also the way to propose the global view in construction of evolutionary theories concerning the biosphere. The peculiarities of the whole can be lost in a reductionistic approach. Teilhard wrote these ideas in letters from China just after an expedition in the Gobi desert, where he envisioned the mystical experience of totality and where he was inspired to write the "Mass on the World." There is the possibility that mystical knowledge, or at least mystical experience, was at the very basis of his research program.

Geobiology

From these connections, Teilhard de Chardin developed the notion of "complexity" and proposed a new science called *geobiology,* the science of continental evolution, which he intended as part of his global program to study evolution. He was able to develop an experimental approach to fossil evolution that showed that evolution is characterised by canalisation and parallelisms. The main parallelism, at least in animals, was the moving of different evolutionary branches toward increasing cerebralization, which Teilhard saw as experimental proof of the directional movement of evolution. The present day discussion about the increasing in complexity of life evolution has in Teilhard one of its forerunners.

Finally, developing Teilhard's vision, evolution is moving toward complexity and consciousness with mechanisms not strictly deterministic: There is room for chance and blind movements. Teilhard looked for philosophical and theological meanings of these mechanisms, and found them in the idea of freedom. He believed that freedom is the third ontological characteristic of the universe suggested by modern science.

These mechanisms are not proof of the lack of purpose or design, but they are compatible with the idea that design implies freedom and that the nondeterministic structure of the universe is the only way to allow room for the free action of the thinking creature. The lack of order at the beginning of the universe gives the thinking creature room for free action in order to conduct general movement toward the Omega Point. The creation and evolution of the Earth is owed to (or thanks to) the freely accepted alliance of creator and the created. The synthesis of interaction of science and faith finds here its climax.

See also CHANCE; CHRISTIANITY, ROMAN CATHOLIC, ISSUES IN SCIENCE AND RELIGION; COMPLEXITY; CONVERGENCE; DARWIN, CHARLES; EMERGENCE; EVOLUTION; FREEDOM; INCARNATION; MYSTICISM; PALEONTOLOGY

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LUDOVICO GALLENI

TELEOLOGICAL ARGUMENT

According to the teleological argument, the order and complexity exhibited by the world are properly attributed to a purposive cause rather than a blind, undirected process. Historically, in looking for evidence of purpose, the argument has focused on the world as a whole, its laws, and structures within the world (notably life). The teleological argument has two recent incarnations. One employs the Anthropic Principle and focuses on the fine-tuning or “just-so” aspects of the physical universe required for human observers. The other constitutes a revival of design-theoretic reasoning in biology and is known under the rubric “intelligent design.”

See also DESIGN

WILLIAM A. DEMBSKI

TELEOLOGY

Teleology, from the Greek *telos* (purpose), is a term generally thought to have been coined by the German philosopher Christian Wolff in 1728. *Teleology* refers to the science of final causes. In Aristotle’s philosophy, there were four sorts of causes, or principles for explaining the nature of things. One of these is the *final cause,* for the sake of which an object exists. Aristotle held that virtually all objects, especially organic objects, have a final cause. It is a principle inherent in them, which disposes them to realize a particular state, which can be seen as the purpose for their existence. It is closely related to the *formal cause,* which is the essential nature (the *form*) of an object. For many objects, the final cause simply is the fullest realization of the formal cause. Aristotle saw organisms as striving to realize their true natures as they grew and developed.

The final cause of an acorn, for example, is a fully grown oak tree. The acorn is naturally disposed to become an oak tree. That is the proper realization of its nature, the reason it exists. The idea of final causality applies most obviously to organisms. It has two forms. One might be called *part-whole teleology*—the parts of an organism exist for the sake of the whole (the heart exists in order to pump blood around the body). The other might be called *goal-oriented teleology*—the purpose of a seed or embryo is to grow into a particular organic form. Aristotle implied that all objects act for a purpose or end, so that even rocks have an inherent purpose for existence, even if it just to be a good solid rock. Aristotle did not appeal to a God for this idea, but saw final causality and formal causality as a principle inherent in all existent objects.

When medieval philosophers in Judaism, Christianity, and Islam took over Aristotelian categories, they explicitly introduced a creator God as a being who gives all things their final causes, and that is itself the final cause of the entire universe, for the sake of which it exists. Thus, one of Thomas Aquinas's (c. 1225–1274) arguments for God is that, since all bodies tend to a goal, they must be directed to it by some being with awareness and intelligence, "and this we call God" (*Summa Theologiae* 1a, 2, 3). Aquinas includes the fact that bodies obey natural laws as a form of final causality. They do not act by accident, but obey the laws as if intended to do so, and this points to the fact that they are so intended.

A marked feature of post-sixteenth century science was its rejection of, or at least indifference to, any doctrine of final causes in nature. Laws of nature were seen as general principles of interaction between objects (perhaps ultimately between atoms), which have no purpose; they just happen to be (perhaps by some unknown mathematical necessity) the way they are. The last remnant of Aristotelian teleology was *vitalism,* the belief that at least organisms are actuated by some immaterial *vital principle* that explains their structure and development. Most biologists reject this notion as unnecessary mystification, and look for purely physical causes of organic structure and development.

The Design argument

In eighteenth-century Europe, a new form of design argument took shape that did not appeal to inherent final causes in things. Instead, it pointed to the way in which the parts of nature cooperate to produce apparently well-designed wholes. A general mechanism of nature is accepted, but that mechanism is seen as producing elegant and desirable states, conducive to the survival and flourishing of organisms, particularly human beings. Nature is a well-designed machine, and its ultimate purpose is the pleasure of conscious human beings. William Paley wrote *A View of the Evidences of Christianity* in 1794, and it became for many years the standard exposition of the design argument. It adduced a host of biological and natural facts to show that nature is an efficient process that realizes highly desirable ends, which shows that nature is designed and that a designer is therefore needed. This could be called the *universal design argument,* since it refers to the general structure of the universe and its laws. Paley also argued that there are many evidences of particular design in nature, from the fact that the eye is perfectly designed for vision to the fact that camels are specially constructed to store water in the desert.

David Hume's *Dialogues Concerning Natural Religion,* published posthumously in 1779, was a devastating critique of such design arguments, and he is generally felt to have refuted Paley's views fifteen years before they appeared. Immanuel Kant, in his *Critique of Pure Reason* (1781), wrote that the design argument was naturally convincing to all, but it was not logically compelling. In particular, it does not show the necessity for an all-perfect creator. According to Kant, there is a definite appearance of design in nature, but there could be another explanation for it.

That other explanation was provided by Charles Darwin's theory of *descent with modification,* or *natural selection,* in the *Origin of Species* (1859). This theory, later broadened into *universal Darwinism* by a number of philosophers, posits that multiple replication and random mutation of organisms, together with ruthless selection by environment, naturally leads over many generations to just the sort of improvements or adaptations that look as if they have been designed, though in fact the mechanism of repeated mutation and natural selection is sufficient to produce that appearance.

Teleology and evolution

To many it seems that teleology has at last been extruded from natural science, and from any reasonable account of the general structure of the universe. Others, however, think this is not the case. In 1928, the Cambridge philosopher F. R. Tennant published his *Philosophical Theology,* in which he gave an extended argument for a teleological view of evolution. In opposition to the Darwinian, or neo-Darwinian, view that mutation is random and undirected, he argued that one can discern a direction in the evolutionary process towards an increase of consciousness, intelligence, and intentional action. Individual mutations are random, in the sense that they are not all directed toward the improvement of the species. But they have an overall propensity, in conjunction with the supportive nature of the environment, to lead to the development of intelligent organisms like human beings. That the environment supports such developments is not an accident, but suggests that the whole cosmic system, in its general evolutionary structure, is well adapted to the production of conscious life forms.

There is, according to Tennant, probably not a particular teleology whereby camels are specially designed to live in deserts. But there is a general teleology whereby organisms that live in deserts continue to produce genetic mutations, some of which will eventually lead to the existence of water-storing organisms like camels. Tennant admits that all this could logically happen by chance, given the existence of laws governing genetic mutation and environmental change. But is it not a puzzle that these laws are just what they need to be to produce organisms like camels and human beings? Darwin himself apparently felt there was a puzzle, but he never solved it.

There would be no puzzle if humans were considered to have no greater value than specks of dust. But if humans are seen as immensely complex integrated structures (and the brain is the most complex structure known in the universe) that value their own existences and may even be of unique intrinsic dignity and value, then there is a puzzle. An evolutionary teleological argument will only work on two conditions—if the evolutionary process is an efficient way of producing its putative goal, and if that goal is indeed of great desirability, perhaps just what an intelligent designer would want to produce.

Darwinians may argue that the process is inefficient or cruel—there are too many mistakes and blind alleys. And they may argue that humans are not of unique value, except, naturally enough, to themselves. Tennant responds that the "mistakes" are necessary parts of a process in which freedom, and therefore some degree of indeterminacy, is an essential part. And the value of human persons lies in their possession of moral responsibility and the ability to relate to one another and to the creator in love.

Is this a scientific argument? It seems not, for the biological facts are not in dispute. It is an argument about how one evaluates organic existence and human personhood. One's attitude toward teleology depends upon evaluative judgments about whether the evolutionary process is "worth it," and about whether humans have a special dignity and moral status.

Belief in God is not necessary to a teleological view—that is, a view that there is a direction in the evolutionary process towards states of unique and unexpected value. One could be a humanist or a Marxist and hold such a teleological view. Many Marxists, for instance, and probably Karl Marx (1818–1883) himself, saw nature as progressively realizing its own inherent drive towards a free and creative society of persons, without the existence of any "external" or omniscient intelligence. If there were to be such an intelligence, it would be the final consequence of the cosmic process, not its precondition.

Among Christian thinkers, the paleontologist Pierre Teilhard de Chardin (1881–1955) has restated a Christian teleological view that owes much to both Darwin and Marx. According to Teilhard, the universe as a whole moves towards greater complexity and higher levels of consciousness. The emergence of human consciousness was a saltation in the process, by which the universe (or parts of it) became capable of conscious self-direction for the first time, so far as we know. The process will continue in the development on Earth of a *noosphere,* in which all individual consciousnesses become progressively unified. The final culmination will be the Omega Point, when the whole material universe will be unified in the life of one omniscient and wholly self-directing spirit. However, Teilhard posits that this Omega Point, being beyond historical time, has in fact always existed as the causal basis of the whole historical process. It is, in fact, God, which, though timelessly complete, realizes itself progressively in cosmic time.

This grand cosmic vision takes evolutionary theory back to its philosophical origins in the work of George Wilhelm Friedrich Hegel (1770–1831), for whom evolution was a gradual self-realization of absolute spirit. This form of evolutionary theory is cosmically optimistic, and committed to a teleological view of the universe as directed towards its final consummation, and perhaps transformation, in the spiritual reality of God. For many, however, this is both too optimistic and too grandiose a vision for the available evidence, which seems to them much more ambiguous in its indications of continued improvement towards a final goal. Just as the dinosaurs were wiped out, so too all life on Earth could be wiped out by some catastrophe, which would eliminate any possibility of purpose in evolution.

Teilhard considered, however, that the cosmic purpose could be completed beyond this physical space-time, in a new environment created by God. So one can hold that there is a purpose in evolution—to produce conscious beings capable of relating to God. But the real final goal is eschatological; it lies in the fulfillment of persons in God beyond the present space-time. This view is clearly not open to empirical testing, though questions of whether persons can survive the death of their physical bodies are relevant to its plausibility.

Teleology in modern thought

Within modern science, there are those, like Michael Behe and William Dembski, who argue that there is still a need to appeal to teleology. They hold that small incremental mutations cannot account for the existence of organs like the eye, which need to exist as a whole in order to function at all. The so-called Intelligent Design argument is about the adequacy of Darwinian explanations to account for all features of organic life.

More widespread, however, are arguments of cosmologists like Paul Davies that the amount of "fine-tuning" of physical constants and laws that is required to produce conscious life in a physical universe is much too great to be due to chance. Some physicists are so impressed by the complex interrelation of physical laws needed to produce life that they think some sort of intelligence must underlie the universe. For most, this intelligence is not a God like that of orthodox religion. It is more like a vast intelligence that is not morally concerned with the lives and happiness of organisms.

Other physicists, like Steven Weinberg, think the hypothesis of an intelligence is superfluous. They would like to see the derivation of the laws of this universe as necessarily following from some impersonal and invariant superset of laws. The supposition that such a superset is necessarily there, however, seems to posit a sort of necessity that science cannot establish. To the religious believer, that necessity might well lie in the intentions of a creator God, who has an ultimate purpose in creating it.

On a less speculative level, there remains the important question, harking back to Aristotle, of whether some sort of teleological, purposive explanation is needed for a complete account of observed reality. In modern science, nomological explanation (in terms of general laws, without reference to purpose) is firmly established as a fruitful explanatory principle. But it is not at all clear whether it is adequate for explaining the facts of human consciousness and social life. Many would argue that explanation in terms of purpose or intention is needed to explain why humans act as they do. After all, they often do things because they intend to. They do seem to have purposes. Others, however, hope to discover nomological forms of explanation that will cover all these factors—probably by investigating sorts of brain activity. The question remains: Is there a teleology, at least in human affairs, that does not reduce to nomological explanation?

Again, this question does not necessarily involve questions of religious belief. But if teleological explanation were found to be necessary for parts of the universe, this might keep open the genuine question of whether the universe has a purpose or goal. In that case, it will be a compelling thought to many that there must be a God, something like a cosmic mind by which such a purpose could be formulated and implemented.

The question of whether teleology is a basic feature of the universe is unresolved. It looks as if such ultimate "scientific" questions go beyond the realms of verifiable fact to questions of the ultimate nature of reality, questions traditionally regarded as philosophical in nature. Consideration of scientific facts is relevant to such questions, but in the end the interpretation of the facts seems to depend on evaluations and on basic attitudes to a materialistic philosophy, both of which go beyond the scientific evidence.

See also ARISTOTLE; CAUSATION; CHRISTIANITY, HISTORY OF SCIENCE AND RELIGION; DARWIN, CHARLES; DESIGN ARGUMENT; ESCHATOLOGY; FREEDOM; GOD; HUME, DAVID; INTELLIGENT DESIGN; ISLAM, CONTEMPORARY ISSUES IN SCIENCE AND RELIGION; JUDAISM, CONTEMPORARY ISSUES IN SCIENCE AND RELIGION; KANT, IMMANUEL; TEILHARD DE CHARDIN, PIERRE; THOMAS AQUINAS

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KEITH WARD

THEISM

Theism is the belief in the existence of a supernatural force or forces, understood to have a personal nature. The term is often used synonymously with *monotheism*. Taken generically, however, theism should include a broad variety of metaphysical positions that are opposed to atheism: polytheism (the belief in many gods), monotheism (the belief in a single God), deism (the belief in a creator God who does not have any subsequent influence upon the world), and panentheism (the belief that the world is within God, although God is also more than the world). Theism contrasts with nonpersonal understandings of ultimate reality, such as the law of karma or the principle of emptiness in Buddhism. Theistic beliefs can set the stage for the science-religion dialogue because these beliefs are not contained within contemporary scientific theories and may stand in *prima facie* tension with them.

See also DEISM; GOD; MONOTHEISM; PANENTHEISM

PHILIP CLAYTON

THEODICY

A theodicy is an argument for the justice of God in the face of evil and suffering in the world. The word *theodicy* is derived from the Greek words *theos* (god) and *dike* (justice). It was first used by the philosopher Gottfried Wilhelm Leibniz (1646-1716) in the early eighteenth century. It is common to talk about the theodicy problem, or the problem of evil, as created by the tension, found mainly in monotheistic religions, between the belief that the world is created by a God who is omnipotent, omniscient, and wholly good, and the observation that there exists immense evil and suffering in the world. Critics argue that such a religious belief is either contradictory or morally unacceptable, and, consequently, can not be true.

Theodicy in world religions

The actuality of evil is a concern in many religions. In Buddhism and Hinduism it is a principal goal to be released from the suffering in the world. In these religions, however, the question of divine justice and its possible conflict with suffering has not been a main concern. For Buddhists and Hindus, individual suffering is the result of each individual's karma; suffering can not be blamed on the gods, for even the gods are submitted to karma.

The problem of evil has mainly challenged Christianity, Judaism, and Islam. In Judaism, the incomprehensibleness of God and of God's justice is stressed. The rabbinical discussion contains several approaches to the theodicy problem. According to a frequent interpretation, suffering is the consequence of human disobedience to God. Jewish teaching also stresses the educational and disciplinary value of suffering. This interpretation is often based on the Old Testament book of Job, in which a righteous man endures immense suffering. In Islamic tradition there is a strong emphasis on the omnipotence of God. This applies not only to the strong tradition of divine predestination, but also to the belief that human beings must obey and surrender to the will of God and that God is not accountable to human moral judgement.

A solution to the theodicy problem presented in classic Christian theology is the idea that evil is a kind of nonexistence or a lack of completeness. Another classic effort is the idea presented by Leibniz that evil is bad only from a limited perspective, and may be necessary for the goodness of reality as a whole. Leibniz used an aesthetic metaphor to illustrate this view: The dark parts in a painting are necessary for the beauty of the whole.

Varieties of theodicy

The nature of God's omnipotence is widely discussed within Christianity. One influential theodicy is to deny that God has the capacity to carry out anything God wants to do. According to this view, the Christian understanding of God as almighty is not identical to the philosophical idea of a capacity to predetermine everything that happens. A modern version of this interpretation can be found in process theology. However, in other Christian traditions, predestination is seen as an important capacity of God.

Another form of theodicy is the claim that suffering is an unavoidable means to a greater end. God's main goal is not to create a paradise on earth, but rather this world is a kind of school to prepare for heaven. Christian teaching often goes beyond the harmonious vision of Leibniz. Not only is suffering seen as an integral part of life, but God is also described as engaging in human misery by taking suffering upon himself through Jesus Christ. Within Christianity there are divergent interpretations of why Christ assumes this vicarious suffering and what function it has.

A frequent argument is the idea that evil is a consequence of human free will. What is commonly called the *free will defense* is the contention that evil in the world can be explained and justified by the free will of human beings. The main idea is that God has granted human beings a kind of independence. The goal of this freedom is to give humans the possibility to become like God and thereby achieve a communion with God, which would be impossible without such freedom. As a consequence, humans may not always act in accordance with the will of God, and they may cause evil and suffering in the world. The free will defense, if accepted, seems to explain only evil caused by humans, but it does not explain natural evil, not caused by humans.

All these efforts to defend the goodness of God in the face of the evil continue to be widely debated, but many give only partial explanations of evil. However, a theodicy must not only provide an intellectually satisfying explanation for evil, the explanation must be morally convincing.

Scientific perspectives on theodicy

Developments in science have interesting consequences for the traditional discussion on the theodicy problem. One important development in biology is the understanding of the role of the nervous system and the possibility of pain in living beings. Physical pain is part of a complex and life-sustaining system for organisms that helps them avoid dangerous situations in which they may be hurt. Pain helps living beings survive by warning them to avoid what causes pain. Individuals whose pain signal system does not work properly have difficulty orienting themselves in the world and avoiding dangers. Similarly, anxiety can be regarded as a by-product or as an integral part of consciousness and imagination, which is highly developed in humans. Consciousness helps people foresee and calculate the future, but it also leads to anxiety.

Another aspect of current biology is the understanding of death as a prerequisite for evolution. From the perspective of evolutionary biology, reproduction of the individual is an instrument for evolution because it facilitates recombination of genes. Thus, the death of the individual is a necessary aspect of life. An individual life is only a link in a series of generations, where the reproduction and extinction of individuals and generations are necessary for evolution.

These scientific insights have inspired new approaches to the theodicy problem because they encourage an understanding of suffering and death as integral parts of reality, hardly to be explained by human disobedience or freedom.

See also EVIL AND SUFFERING; FREE PROCESS DEFENSE; FREE WILL DEFENSE

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ULF GÖRMAN

THEOLOGICAL ANTHROPOLOGY

Theological anthropology concerns humans beings and their relationship with God. It addresses humans as created in the image of God, with a special qualitative relation to God compared to other species. Sin is the corruption of the relation, indicating that humans are constitutionally opposed to God. Theological anthropology also deals with the restoration of the human relationship with God through the life, death, and resurrection of Jesus Christ. Theological anthropology can, but need not, be carried out in dialogue with other disciplines studying different aspects of humanity, and it can offer a theological framework for the interpretation of these. Scientific contributions claiming to have positive bearings on a religious understanding of humanity usually relate to the doctrinal content of theological anthropology.

See also IMAGO DEI; SIN

JAN-OLAV HENRIKSEN

THEOLOGY

Theology is the cognate of the ancient Greek word *theologia,* meaning discourse or study of the gods or divine things, as in Plato's *Republic*. The term was retained when monotheistic conceptions of God became much more abstract than references to an individual god, as in neo-Platonic conceptions of the One, the Thomistic act of *Esse* (being), and twentieth-century theologian Paul Tillich's Ground of Being. In contemporary usage, the term refers to the comparative discourse among religions, some of which, such as Buddhism and Confucianism, do not have serious conceptions of gods but rather alternatives to monotheistic notions.

See also THEOLOGY, THEORIES OF; THOMAS AQUINAS

ROBERT CUMMINGS NEVILLE

THEOLOGY, THEORIES OF

The term *theology,* in its Greek cognate roots, means discourse about or study of gods or divine things. It was not originally distinguished from philosophy about gods and divine matters, and for some contemporary thinkers, such as process theologians, theology retains that connection with philosophy. These kinds of issues raised regarding the relationship of science and religion depend in many respects on one's conception of theology as it pertains to rationality, authority, and the communities and sources of theology.

Early Christian thinkers used the term *theology* (or its cognates) to describe their expressions of the Christian faith to other Christians and to non-Christians. In this context, theology had an apologetic function, that is, explaining and justifying religious beliefs and practices to people for whom explanation and justification is needed, including Christians themselves. In late Christian antiquity, as represented, for example, by Augustine of Hippo (354–430 C.E.), theology as reflection on religious beliefs and practices embraced philosophy, history, interpretation of scripture, appeal to the scientific understanding of the day, rhetoric, and other modes of discourse as they might bear upon the divine, as found in Augustine's *The City of God.* Although the ancients were self-conscious about these modes of thought, they did not focus on theology as a special mode of thought.

By the Christian middle ages, however, theology was understood theoretically in a three-fold way. A distinction was drawn, for instance by Thomas Aquinas (c. 1225–1274), between natural theology and revealed theology. Natural theology consisted in what could be known by reason without the aid of revelation, and revealed theology was based on revelatory sources. Although there were many sources for this distinction, comprehensively explored in Etienne Gilson's classic *Reason and Revelation in the Middle Ages* (1938), a primary source was the extraordinarily fruitful dialogue between Christians and Muslims. They shared a common reason that was exercised in rational argument and in the interpretation and criticism of Aristotle. They disagreed about revelatory sources and hence about some doctrines that were particular to those sources. Aquinas himself believed that truth is one and consistent, and that natural and revealed theology must therefore be complementary. Some (e.g., Roger Bacon, c.1212–c.1292) said that revelatory claims that disagree with reason must be superstitions whereas others (e.g., William of Ockham, c.1290–1349) said that revelation trumps reason and takes the form of paradox when it does so. Although the distinction between reason and revelation was not sharp until the European medieval period, antecedents of these emphases are ancient; Origen (c.185–c.254), for instance, interpreted revelatory sources so that they conformed to reason, and Tertullian (c. 160–c.225) delighted in paradoxical irrationality of scriptural theology.

In addition to the theory that theology is either natural or revealed, the medieval period saw the development of theology in a rhetorical mode, as in Bernard of Clairvaux (1090–1153). In this mode, theology arises from the interpretation of scriptures in sermons and inspirational writings, often taking the form of allegories. Rhetorical theology to this day is often suspicious of natural and revealed theology for attempting to make theology a science or explanatory description of divine matters, preferring instead that theology move the soul to greater spiritual competence.

Whereas the term *theology,* by the medieval period, was used mainly within Christian circles, the discourse itself was shared with Muslims and Jews. Islam and Judaism developed rational modes of theology something like Thomistic natural theology, and also revelational modes of theology, sometimes in complementary and sometimes in competing forms relative to natural theology.

From the vantage point of the twenty-first century, the term *theology* has expanded its scope of subject matter. Ancients such as Plato could use the term *theology* to refer to the study of gods while at the same time believing that there are higher principles than gods, the Form of the Good in Plato's case. Under the impact of the great monotheistic religions of West Asia, however, theology came to interpret only the highest principles as divine and hence the object of theology. By the end of the twentieth century, the term *theology* had been generalized to mean discourse about ultimate matters regardless of whether ultimacy is interpreted in a theistic way, as discussed, for instance, by the Comparative Religious Ideas Project in *Ultimate Realities (2001*). Some forms of Hinduism are plainly theistic, and these contest with others that are nontheistic, all as theology. Various kinds of Buddhism, like many kinds of Hinduism, represent the existence of hundreds or thousands of gods without treating them as ultimate. Buddhist theology uses concepts such as emptiness, suffering, attachment, Buddha-mind, and enlightenment, to treat ultimate matters. Daoism also represents many non-ultimate gods but discusses the ultimate in terms of the Dao. Confucianism regards most beliefs in gods as superstitions and interprets the ultimate in terms of Heaven and Earth, or Principle and Material Force.

Theories of theological publics

Contemporary theories of the nature of theology can be understood in terms of the publics they address, the sources and justifications to which they appeal, and their mode of logical presentation.

Acknowledging that there are different types of theology, some theorists distinguish them by the publics to which they are addressed. One of the most influential recent typologies was developed by David Tracy in his *The Analogical Imagination* (1981). Admitting that the boundaries are not fixed, his typology says that systematic theology takes the Church (or a religious community, Christian in Tracy's case) for its public, fundamental theology takes the academy for its public, and practical theology takes society, usually addressed by a social movement, as its public. Systematic theology thus is thinking in, by, and for a religious community, framed in the language of its historical symbols, and aimed to give a coherent and clarifying account of the community's beliefs. Fundamental theology, as Tracy explained it, is open to philosophical considerations that might undermine a religious community's assumptions and at any rate has to employ rational discourse to engage members of the intellectual community (the academy and its neighbors) who might not be members of the religious community. Practical theology, for Tracy, aims to understand the religious implications of social conditions and perhaps to change them.

One problem with Tracy's typology is that much theology that takes place within the exclusive public of a religious community is not systematic. In *On Christian Theology* (2000), Rowan Williams provides an alternative typology of celebratory, communicative, and critical styles. Celebratory theology arises from the scriptural symbols, liturgies, and hymnody of a religious community and weaves these together so as to exercise the symbolic and affirmative thinking of the living community, a kind of theology in direct lineage from rhetorical theology of Bernard of Clairvaux's sort. Williams points out that this is unstable when the community exists within a larger environment and that communicative theology arises as church theologians interact with the languages and concerns of others. The use of Greek theology by the early Christian apologists, the engagement of Islamic theology in the medieval period, and the use of Marxism in recent Christian theology are examples of this.

Celebratory theology is primarily focused on the public of the religious community whose symbols it exercises. Communicative theology has the public of some elements of the larger environment as engaged by the religious community. Sometimes those engagements go so far as to call into question the continuities of the community's faith with its participation in larger discourses, and sometimes the very meaningfulness of the celebratory concepts and symbols. Then theology becomes critical in the sense of objectifying and questioning the very meaning and truth of original affirmations celebrated by the religious community. The result can be a conservative reaffirmation of them, as in the theology of the Yale School as represented by George Lindbeck in his *The Nature of Doctrine* (1984), or a radical break from traditional notions, as represented by Mark C. Taylor in *Erring: A Postmodern A/Theology* (1984). Williams cites classical apophatic (that is, negative) theology as preeminently critical. The public for critical theology is anyone with a relevant critical argument.

Both Tracy's and Williams's theories of types of theology assume that theology begins from and is rooted in a religious community (Christian in both cases). Their distinctions of publics have to do with how far theology ventures from the symbolic language and doctrines of the community itself, and in both cases they would call all their types "Christian" theology. Sometimes this community-based theology is called "confessional," in reference to the traditional confessions that constitute the identity boundaries of some, though not all, religious, even Christian, communities. Tracy's fundamental and Williams's critical types of theology call the confessional identity into question, but themselves are defined by reference to the confession in so doing.

The confessional publics, including the outreach in fundamental and critical theologies, can be contrasted with scientific publics. Some theologies, for instance those of the Yale school, would treat the religious and scientific publics as defined by separate communities, each with its own cultural-linguistic system (Lindbeck's category), such that the membership of a person in both communities would be adventitious. Much of the late twentieth–century religion and science discussion, however, had to do with whether the beliefs from the different religion and science publics could be made compatible, as in the work of Nancey Murphy in *Theology in the Age of Scientific Reasoning* (1990) and John Polkinghorne in *Science and Christian Belief* (1994). Such discussion does not question extensively the results of the confessional theologies or sciences in their respective publics, or cause them to learn from one another so as to change; rather it attempts reconciliation of the publics left as they are.

Yet another kind of public for theology is simply the global array of perspectives that might have something to contribute to inquiry about divine matters (broadly understood). Although individual theologians aiming at this global public might come from a specific religious tradition, the orienting base is, at first, comparative religions. The language of theology for a global public includes extremely vague theological categories that might be specified in different and perhaps incompatible ways by different religions. Ultimacy, as discussed above, is a vague category specified differently by God, the Dao, and so forth. Debates in global theology both adjudicate these differences and aim to develop claims more adequate than any tradition's symbols by themselves. Moreover, not only religions, but also imaginative literature, the arts, and indeed the sciences have contributions to make to inquiry about theology's topics. All these disciplines have articulate bearings on ultimate matters. So the orienting base of theology with a global public is not only comparative religions but all the disciplines that might bear upon the topic. In this case, scientific publics do not stand in contrast to theological ones but are components of the discipline of theology insofar as they have relevance to ultimate matters. For theology in a global public, no particular issues of reconciling religion and science are fundamental but only questions of what can be learned from each for understanding theological matters. The language of global theology draws on many religious, imaginative, artistic, and scientific sources, as well as practical politics and ethics. Twenty-first-century theology aiming at a global public is stimulated by global problems such as in ecology and distributive justice, and aided by the rapid communication of thinkers in many fields and cultures about these global problems.

Sources for theology

Theories of theology are sometimes distinguished by what they take to be the most important sources for theology and the roles those sources play. The commonly cited sources are scriptures, such as the Vedas, the Hebrew and Christian Bibles, and the Qur'an; historical traditions as expressed in creeds, commentarial texts, and special teachings; experience, usually contextualized, as in mysticism, popular piety, and liberation movements for the poor or marginalized; and reason, as in philosophy, the arts, imaginative literature, sciences, common sense, and practical endeavors such as politics and law.

Most religious traditions have employed all these sources in their theologies, but different theories of theology have emphasized one or several over the others. A fundamental distinction between theories of theology is whether the theory takes one or several of these sources to be absolutely authoritative in the sense of trumping claims arising from the other sources. The alternative theory is that theology respects all or some of these sources as important authorities but considers all to be liable to reinterpretation by some or all of the others. The theories claiming that some one or several sources must be absolutely authoritative include biblical fundamentalisms in Islam and Christian Protestantism, deference to infallible elements of tradition in Roman Catholicism, insistence that a theology is valid only if it supports women's experience in some forms of feminism, and rationalisms such as Charles Hartshorne's process theology. Hans W. Frei's *Types of Christian Theology (1992),* a classic of the Yale School, classifies theologies according to whether their sources are primarily biblical, philosophical, or social scientific in various combinations, while holding that the public for theology is the Christian community.

Because of the rise of modern science in connection with the Enlightenment, the Protestant Reformation, and the Roman Catholic Counter-Reformation in Europe, a special story needs to be told about the modern connection of theological sources with science. Martin Luther and other reformers attacked the authority of tradition and traditional church institutions to assert the primary and almost exclusive authority of the Christian Bible—the doctrine of *sola scriptura*. This had the force within much subsequent reformed Protestant theology of subordinating, marginalizing, or even dismissing the rich philosophical, literary, and scientific language of medieval Christian theology. Protestant theology found itself constrained to use the language of the Bible with its serious personifications of God and highly political imagery of the divine kingdom. Conceptions of God as the transcendent One in Christian neo-Platonism, or as pure Act of Esse in Thomism, found little place in Protestant theology, which developed increasing suspicion of metaphysics. The reformers' emphasis on *sola scriptura* had the opposite impact on the Roman Catholic Counter-Reformation, namely the fixing upon a scholastic form of theology as a near unalterable and absolute authority.

Both Protestant biblical theology and Roman Catholic scholastic theology were seriously ill-equipped to respond to the burgeoning findings of modern science that might have been a delight and inspiration to a continuing imaginative and creative development of the medieval synthesis of philosophy, scripture, and politics. As a result, a tradition of philosophical theology developed parallel to and often in hostile relation to both Protestant and Roman Catholic church theologies, with thinkers who themselves were often also scientists. The greats include René Descartes, Thomas Hobbes, John Locke, Gottfried Wilhelm Leibniz, Benedict de Spinoza, George Berkeley, David Hume, Immanuel Kant, Georg Hegel, Søren Kierkegaard, and Alfred North Whitehead. That list includes Roman Catholics, Protestants, Anglicans, and a Jew (Spinoza); Berkeley was an Anglican bishop. Yet their theologies all were outside the mainstream of their church communities, however influential they might have become later. All those thinkers understood theology to require a reconception of God and creation in relation to the findings of modern science. Neither the biblical representations of God nor the Roman Catholic scholastic conceptions, which had become fairly authoritative for their religious traditions, were adequate in the scientific world.

At the end of the twentieth century, discussions of theology and science were torn between two sets of assumptions. One is that religion or theology is to be represented by a defense of what some Protestants call the "classical" conception of God: a personal being with conscious subjectivity and infinite power, knowledge, and goodness who can interact with the world in ways at least analogous to the ways described in the biblical narratives. Keith Ward's *Religion and Creation* (1996) contains an elegant defense of an Anglo-Catholic version of this view. The question science raises for religion under this set of assumptions is whether the conception of God as a personal being with agency in the world can be made compatible with science. The other set of assumptions is that the conception of God needs to be rethought as science causes us to reconceive other foundational aspects of reality. Process theologians following from Alfred North Whitehead in *Process and Reality* (1929) and Charles Hartshorne in *The Divine Relativity* (1948) claim there is a need for a "neo-classical" conception to replace the "classical" conception of God. By "classical" the process theologians mean the Thomistic idea, not the biblical idea of God as a personal being that the other set of assumptions calls "classical," though Whitehead found both problematic. Many philosophical approaches other than those of process theology contend within the second set of assumptions. Some have great potential for relating to religions other than Christianity, as in existential theologies such as Paul Tillich's in *Systematic Theology* (1951–1963), Heideggerian theologies such as John Macquarrie's in *Principles of Christian Theology* (1966), Karl Rahner's in *Foundations of Christian Faith*(1989), and pragmatic theologies such as Charles Sanders Peirce's in his 1908 essay "A Neglected Argument for the Reality of God."

All the world's theological traditions are affected by modern science in that they have to reexamine the relation of contemporary practice to ancient texts and symbols. The dialectical relation between Reform, Orthodox, Conservative, and Reconstructionist Judaism developing over the last two centuries is a case in point. The introduction of Western science into China in the nineteenth century caused both a revolution within Confucianism as it westernized and revolutions against Confucianism, most notably the Marxist. The theological traditions of South Asia were greatly dislocated by European imperialism from the seventeenth through the nineteenth centuries, and were recovered in the nineteenth and twentieth centuries in forms usually positively related to science. Some of these forms enjoy the positive relation by distancing religion as spiritual from science as material; others claim scientific standing for ancient techniques and ideas. Relating to "Eastern Mysticisms" generally, Fritjof Capra's popular *The Tao of Physics* (1975) reconciles science to mystical ultimates by modifying both beyond what the home communities recognize easily.

How theology related to science at the end of the twentieth century depended very much on the kind of authority different conceptions of theology gave to scripture and scholasticism, on the one hand, and to philosophical reason and the sciences as sources for theology on the other. For many of the philosophical traditions of theology, science has been a more important source for conceptions of God than scriptural symbols, with scriptural symbols being given interpretations based on the scientifically shaped philosophical conceptions.

Modes of theology

Few, if any, pure modes of theological argument exist, although in theory four have been defended as particularly important: expository, hypothetico-deductive, practical, and dialectical inquiry.

The expository mode takes as given, although not necessarily infallible, some core set of texts or claims, and seeks to unfold, elaborate, interpret, and bring them to relevance. Williams's celebratory and communicative theologies, Tracy's systematic theology, classical biblical theologies, and commentarial theologies in all religions have this mode.

The hypothetico-deductive mode, as illustrated for instance in Peirce's "A Neglected Argument for the Reality of God" and Whitehead's cosmological scheme in *Process and Reality,* elaborates an abstract scheme of conceptions that is then treated as an hypothesis to explain the world and God or ultimate matters. This mode is explicitly derived from a conception of how science works, and emphasizes that the conceptions are hypotheses whose plausibility consists in their capacity to interpret reality as well as in their consistency and coherence. Theology in this mode is heavily empirical. Wolfhart Pannenberg's proleptic theology, which says that his particular conception of Christian theology will be proved right in the End Time, and John Hick's conception of eschatological verification, are empirical in a different sense.

The practical mode of theology combines both expository and perhaps hypothetico-deductive philosophy as well as other forms of analysis to interpret the religious situation and to develop strategies for religious response. The situation might call for reform of social circumstances as in liberation theologies, the production of art and culture, the care of a religious congregation or community, or service to people in times of disaster. Science relates to practical theology both as offering important means of analysis of the situation to be addressed and in some instances as providing instruments of action.

Theology in the mode of dialectical inquiry focuses on the topics of theology—God or ultimacy and the bearing of this on human life—and looks to all possible sources and to all the modes of argumentation for learning from these sources. The word *dialectic* has been used to mean some kind of unfolding of reason from within, as in the theories of Hegel or Thomas J. J. Altizer, but that is not the meaning here. Dialectical inquiry means combining as many different modes of thinking as exist in religions, the arts, sciences, and practical domains of experience so as to learn what they might teach about ultimacy. The combinations and the limitations of the various modes of thinking can only be adjudicated in particular arguments. Dialectical inquiry is simply making the best case in the sense articulated by the contemporary historical theologian Van Harvey in *The Historian and the Believer* (1966), and is the mode most appropriate for theology in a global public.

See also THOMAS AQUINAS; NATURAL THEOLOGY; PROCESS THOUGHT; REVELATION

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ROBERT CUMMINGS NEVILLE

THERMODYNAMICS, SECOND LAW OF

The Second Law of Thermodynamics expresses a fundamental and limiting characteristic of all physical systems: In any closed system, the measure of disorder, or entropy, of that system must either remain the same or increase. Equivalently, in any isolated system, the amount of energy available for work—the free energy—must either remain the same or decrease. Processes in which the entropy remains the same are reversible; those in which the entropy increases are irreversible, that is, there is no realistic possibility of recovering the initial state of the system. It is principally because of the Second Law of Thermodynamics that all physical and biological systems are destined for eventual dissolution or death, even the universe itself. Without the continual input of work, energy, or material (food), every system (not necessarily closed) moves towards equilibrium, which is characterized by maximum entropy. Organization, order, and life require that the system in question be maintained far from equilibrium, and this requires input of energy from outside—from its environment.

Formulations

Long before the Second Law was expressed in terms of the change in entropy of a closed system, Sadi Carnot (1796–1832) formulated it in terms of heat and work: It is impossible to convert heat back into work at a given temperature. Although work can be converted into heat at a given temperature, the reverse cannot be effected without other changes. Heat will never travel up a temperature gradient on its own. It is only with further work that heat can be transferred from a body or a system at a given temperature to one that is either at the same temperature or at a higher temperature. Of course, heat can indeed flow from a hotter system to colder system without any work being necessary. Thus, another formulation of the Second Law is that heat cannot flow from a given system to a hotter one without work being done. A refrigerator must use energy in order to function. Other expressions of the Second Law are: A perfect heat engine is impossible to construct (Lord Kelvin's formulation), and similarly, it is impossible to construct a perfect refrigerator (Rudolf Clausius's formulation).

The clearest and most applicable formulation of the Second Law of Thermodynamics, however, is: During any process the entropy of any isolated system must either remain the same or increase. But what is entropy? It is sometimes defined as the measure of the unavailability of the energy of a system for work. An isolated system in perfect equilibrium has maximum entropy and thus has no energy available for work. It is now more usual, however, to define entropy by employing the statistical mechanical underpinnings of thermodynamics in terms of the number of microstates available to the system at a given energy. Any given macroscopic state of a system (given, for instance, by its temperature, pressure, and volume) corresponds to many different possible microscopic states of that system (arrangements and velocities of the molecules constituting it). The larger the number of possible microstates corresponding to a given macrostate, the larger the entropy of the system, and the larger the disorder of the system. The maximum entropy—and therefore the maximum disorder—is given by the situation in which the actual macrostate of the system possesses the maximum number of accessible microstates for the energy it contains. This is the state of equilibrium. Thus, what is really significant is not the absolute value of the entropy for an isolated system, but rather how far its entropy is from the maximum—how far away the system is from equilibrium. As already mentioned, this also indicates how much free energy (for work) is available in it.

The determination of the entropy and the maximum entropy, and therefore the application of the Second Law of Thermodynamics to gravitating systems, such as a cluster of stars, the galaxy, or the universe, is somewhat more complex than it is for non-gravitating systems. This is because the total entropy of such systems must include gravitational entropy as well as thermodynamic entropy, and the lowest gravitational entropy state of a system is realized when it is perfectly homogeneous—no clustering or clumping. A homogeneous self-gravitating system is obviously far from equilibrium. As the matter gradually coalesces and clumps, the gravitational entropy increases, releasing free energy through heat and radiation, which is now capable of being harnessed for work. Eventually the cores of some of these mass concentrations become hot enough for the initiation of nucleosynthesis, and even more free energy is released. Maximum gravitational entropy is achieved when the whole system becomes a single black hole. For that to happen all the free energy of the system has to be exhausted.

What was the origin of the initial extreme gravitational disequilibrium? Possibly it was an inflationary phase of the universe almost immediately after the Big Bang, during which the universe expanded incredibly fast (exponentially) in a very short time; perhaps it was certain quantum-gravity effects even earlier during the Planck era that rendered the initial state of our part of the universe very smooth. How will the universe as we know it end? In entropic death or heat death. This will occur when either the universe evolves to become something like a single black hole, or when it expands so much and so rapidly that gravity is no longer effective in drawing together whatever relic mass concentrations remain (particles or black holes). In either case, a state of equilibrium has been reached; the entropy of the universe is a maximum, and no useful energy for work or for nourishment can be found.

Sometimes people mention that life-generating or life-maintaining systems do not obey the Second Law of Thermodynamics, because in generating order they are lowering the entropy. But, in fact, they are perfect examples of the application of the Second Law. The system one must consider in this case is not just the living organism itself, nor just the community of living organisms in question, which are *not* isolated systems (they are in crucial and continual interaction with their environment), but rather the entire ecological system itself as isolated from what occurs outside it. Yes, the entropy of each organism and community of living organisms is kept relatively low, but only at the expense of increasing the entropy of their surroundings. The entropy of the whole isolated ecological system is increasing. If one isolates organisms in a box with a certain limited amount of food and available energy and no interactions with the world outside the box, the organisms will live and reproduce for a certain length of time. But eventually the available energy will be depleted and the food supply (both the food they started with and the food they subsequently produced) will run out, and everything in the box will reach the equilibrium that is death.

Implications for religion

The inescapable limits placed on physical and biological reality by the Second Law of Thermodynamics confront theology and religion with a serious challenge. If all is finite, transient, and destined for death and dissolution, what meaning and hope can theology and religion legitimately assert? How is the eternal destiny proclaimed by religions to be understood, and how is this seemingly insuperable limit to be transcended? These are eschatological questions. There are also questions relating to natural evil. Assuming that God works through all the laws of nature, including the Second Law, to create and maintain the world, how can one conceive God as the creator of a world in which death, disease, suffering, and the exploitation of resources is not only pervasive but essential? Finally, according to religious perspectives, the Second Law of Thermodynamics cannot have the last word. The "new heavens and the new earth," though in continuity with this world, are promised to be devoid of the transience, suffering, death, and natural evil that accompany human existence.

See also BIG BANG THEORY; DEATH; ENTROPY; ESCHATOLOGY

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WILLIAM R. STOEGER

THINKING MACHINES

The term *thinking machine* (or intelligent machine) refers to a computer or a robot that has human intelligence. No such machine exists as of 2002, and whether it can be built in principle and how many years of research this would take is a matter of much dispute. The feasibility of thinking machines has been promoted by representatives of strong artificial intelligence (AI), such as John McCarthy, Marvin Minsky, and Doug Lenat. A principle formal argument against conscious and thus intelligent machines has been posed by mathematician and physicist Roger Penrose. To testify that a computer agent is a thinking machine it would have to pass the Turing Test.

See also ARTIFICIAL INTELLIGENCE; ROBOTICS; TURING TEST

THIEMO KRINK

THOMAS AQUINAS

Thomas Aquinas held that revelation was essential for grasping truth of faith but he relied on reason to understand the world that God created. Mindful of this division, Thomas warned against dogmatic interpretations in areas of faith that might have to be abandoned if subsequent natural evidence falsified them. Convinced that Aristotle's (384–322 B.C.E.) natural philosophy provided the most accurate interpretation of cosmic operations, Thomas refused to Christianize natural philosophy and, to the greatest extent possible, he applied reason to both science and theology.

Life and works

Thomas Aquinas was born near Monte Cassino, Italy, around 1225. He was the youngest of nine children. After elementary education in the abbey of Monte Cassino, Thomas was sent to Naples in 1239, where he studied at the University of Naples. In 1244, while still at Naples, Thomas entered the Dominican order, contrary to the wishes of his family. From 1245 to 1252, Thomas studied at Paris and then Cologne. At Cologne, and perhaps at Paris, Thomas's teacher was Albert the Great (Albertus Magnus) (c. 1206–1280), one of the great scientists and natural philosophers of the Middle Ages and a thorough student of Aristotle's writings. After training as a theologian, Thomas became a professor of theology at the University of Paris (1256–1259). He spent the years between 1259 and 1268 in Italy serving different popes at their papal courts. During 1269 to 1272, Thomas returned to another professorship at the University of Paris, after which he returned to Naples, where his health began to fail. Thomas died in 1274 while on his way to the second Council of Lyons.

Thomas was a prolific author who left approximately fifty works that have been thus far identified. He wrote on numerous topics, the most significant of which are his theological treatises, especially his famous *Summa of Theology* (Summa theologiae), commentaries on books of the Bible, and commentaries on various works of Aristotle, especially those on natural philosophy, which include Aristotle's *Physics, On the Heavens, On Generation and Corruption, Meteorology,* and *On the Soul.* In addition, Thomas composed sermons, letters, and replies to queries.

Thomas on the relationship of faith and reason

Issues of science and religion in the Middle Ages involve the relationship between natural philosophy and religion. By the time Thomas began writing, Aristotle's works on logic and natural philosophy had been adopted as the basic curriculum in faculties of arts of medieval universities. Because Aristotle's natural philosophy raised issues that were directly relevant to theology and the Catholic faith, it was inevitable that Thomas, who was both a theologian and a natural philosopher, would have to confront those issues in his works on theology and natural philosophy.

When Thomas dealt with issues of science and religion, he was guided by his overall view of the relationship between faith and reason. Thomas emphasized the importance and power of reason, but insisted that it was inadequate to gain knowledge of unseen things, such as God, for which faith and divine revelation are essential. For knowledge of the physical cosmos and its regular operations, however, reason—embodied in the works of Aristotle—was Thomas's instrument for understanding those operations. But reason was also an instrument for the study of theology. In the very first question of his *Summa of Theology,* Thomas asked whether theology is a science and replied affirmatively. He is usually regarded as the scholar who gave credence to the claim that theology is a science, a claim that was widely assumed in the late Middle Ages.

Two principles derived from the early Christian leader Augustine of Hippo (354–430 C.E.) and expressed in the *Summa of Theology,* guided Thomas in his explanations of natural phenomena. He insisted: (1) that the truths of Scripture must be held inviolate, but that (2) no passage in Scripture should be interpreted rigidly and dogmatically because it might later be proved false by convincing arguments, thus leading to a loss of credibility that would inhibit nonbelievers from adopting the faith.

Thomas and Aristotle

Although Aristotle's natural philosophy formed the basic curriculum in the arts faculties of medieval universities, those aspects of his work that conflicted with basic Christian beliefs evoked opposition through most of the thirteenth century. In the 1260s, and 1270s, when Thomas was writing, the opposition was led by the Franciscan theologian Bonaventure (1221–1271), whose neoconservative Augustinian colleagues eventually prevailed upon the bishop of Paris to condemn certain of Aristotle's articles deemed offensive to the faith; thirteen articles were condemned in 1270 and 219 articles were condemned in 1277, three years after the death of Thomas. Since Thomas was a supporter of Aristotle's philosophy, as were many Dominicans, some of the hostility was plainly directed against him and his colleagues. It was not until 1325, two years after the canonization of Thomas Aquinas, that the bishop of Paris, Stephen Bourret, revoked the condemnation of all articles condemned in 1277 that were directed against the teachings of Thomas.

The most significant idea condemned in 1277 was Aristotle's claim for the eternity of the world, which was denounced at least twenty-seven times in a variety of contexts. In a treatise he titled *On the Eternity of the World,* Thomas neither rejected nor accepted the eternity of the world. By absolute power, God could have created a world that was coeternal with God. For as Thomas argued, "The statement that something was made by God and nevertheless was never without existence . . . does not involve any logical contradiction." If God wishes, God can choose not to precede any effect God decides to produce, and thus God can make the world eternal. Although God could make the world coeternal with God, an eternal world would still be a created effect, because it is wholly dependent on an immutable God, thus guaranteeing that the world cannot be coequal with God. Of the articles condemned in 1277, Article 99 was probably directed against Thomas's interpretation of the eternity of the world. Thomas's approach to the question of the world's duration proved popular and found supporters up through the Renaissance. Bonaventure and others were convinced that Aristotle had denied the personal immortality of the soul, but Thomas thought Aristotle had believed it.

Since Aristotle firmly believed that every material thing is derived from previous matter, he would have been opposed to the Christian doctrine of creation from nothing. Article 185 condemned the view that something could not be made from nothing. Indeed, the Fourth Lateran Council of 1215 had declared belief in creation from nothing to be an article of faith. On this issue, Thomas, and all Christians, were compelled to reject Aristotle's interpretation.

Thomas's conception of the physical world and its operations was basically the same as that held by Aristotle, from whom he derived it. In his commentaries on Aristotle's natural philosophy, Thomas considered the numerous problems Aristotle presented, accepting most of Aristotle's solutions, but disagreeing on some important issues. Although Thomas believed with Aristotle that the existence of void spaces was impossible, he disagreed with the absurd consequence Aristotle deduced from the assumption of motion in a vacuum, namely that because of an absence of material resistance, a body would move instantaneously in a vacuum and, as a consequence, no ratio could obtain between motions in a hypothetical void and motions in a space filled with matter. Thomas rejected these conclusions. A body falling or moving in a void space would have a definite speed and take a definite time to move successively between two distant points. This is so, argued Thomas, because any distance in a three-dimensional void has prior and posterior parts that a body must traverse to get from one point to another, which requires time. Hence there could indeed be a ratio between motions in a vacuum and motions in a plenum.

In a letter to a soldier, Thomas explained how bodies could perform actions that do not follow from the nature of their constituent elements, as, for example, the attraction of a magnet for iron. Thomas regarded such actions as occult, explaining the causes of such phenomena by the behavior of two kinds of superior agents: (1) celestial bodies, or (2) separate spiritual substances, which included celestial intelligences, angels, and even demons. A superior agent can either communicate the power to perform the action directly to an inferior body, as is the case with the magnet; or the superior agent can, by its own motion, cause the body in question to move, as, for example, the moon causes the ebb and flow of the tides.

Whatever disagreements Thomas had with Aristotle, whether doctrinal or otherwise, it is obvious that Thomas was an Aristotelian in natural philosophy. As an Aristotelian natural philosopher and a professional theologian, one may appropriately inquire how Thomas related natural philosophy and theology, the medieval equivalent of the relations between science and religion. Thomas followed in the path of his teacher, Albert the Great, and generally refrained from introducing theological ideas into his treatises on natural philosophy, whereas he did not hesitate to introduce natural philosophy to elucidate his theological discussions. As a theologian doing natural philosophy, Thomas could easily have resorted to theological appeals and arguments in his natural philosophy, but he did not think it appropriate to do so. As he explained in a reply to one of forty-three questions sent to him by the master general of the Dominican order, "I don't see what one's interpretation of the text of Aristotle has to do with the teaching of the faith." Thomas refused to Christianize Aristotle's natural philosophy and to confuse natural philosophy with theology. In this, Thomas followed the practice of most medieval theologians and natural philosophers.

See also ARISTOTLE; AUGUSTINE; CHRISTIANITY, ROMAN CATHOLIC, ISSUES IN SCIENCE AND RELIGION; CREATIO EX NIHILO; CREATION; GOD

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EDWARD GRANT

TIME

See SPACE AND TIME

TIME: PHYSICAL AND BIOLOGICAL ASPECTS

Insofar as science aims at reconstructing the laws of nature, which describe the temporal development of nature's physical constituents and allow for predicting future events out of data derived from past events, time is a fundamental and crucial notion of empirical sciences. Science, however, does not deal with time itself, but with changes and events in time. Consequently, what really matters in science "is not how we define time, but how we measure it" (Feynman, p. 5-1). As such, time constitutes the realm, rather than the object, of scientific investigation. The nature and character of time must be derived from interpretation of the basic structure of science and its method. And because time does not refer to external objects of investigation, but to the presupposed internal order of physical phenomena, it is closely related to human experience and the human perception of time, which is the sequential, nonspatial order of events, structured by the relation of cause and effect. Unlike space, time as sequential order shows a fundamental asymmetry between the past (fixed in documents, which can be investigated) and the future (still to come and not totally fixed—it can only be predicted). People can remember the past but not the future; people can alter the future, but not the past. The astronomer Arthur S. Eddington (1882–1944) was the first to speak of the "arrow of time," which points from the past to the future, to symbolize this fundamental asymmetry.

The physics of time

The crucial question of the interpretation of time in physics and biology is whether this asymmetry is due to physical laws, or whether it is a subjective illusion due to the human experience of time. The laws of both classical and relativistic physics, as well as the basic equations of quantum physics, are time reversal invariant and provide no scientific ground for an arrow of time. On the other hand, an irreversible directedness of time does turn up in empirical sciences related to different phenomena:

(1) According to the Second Law of Thermodynamics, disorder (entropy) increases in a closed system from past to future.

(2) The measurement of quantum events constitutes an irreversible difference between past and future.

(3) Biological systems and their evolution constitute a historical development from past to future.

(4) The universe is expanding in time.

Because time and irreversibility seem to have different meanings in different physical theories, and because the notions of causality involved are a matter of dispute as well, a comprehensive and commonly accepted interpretation of time in natural sciences is neither at hand nor in sight. This entry will refer to some aspects of an ongoing discussion.

Newtonian time of classical physics. In his *Mathematical Principles of Natural Philosophy,* Isaac Newton (1642–1727) distinguishes between *absolute* and *relative* time: "Absolute, true, and mathematical time . . . flows equably without relation to anything external, and by another name is called duration: relative, apparent, and common time, is some sensible and external (whether accurate or unequable) measure of duration by the means of motion, which is commonly used instead of true time; such as an hour, a day, a month, a year" (p. 6). The notion of absolute time is crucial for Newtonian physics because its First Law of Motion implies that a body on which no forces act moves uniformly in a straight line at constant speed, or it is at rest. Only against the background of absolute time and space can rest and equable translation as free from external influence stand out against those deformations of motion that indicate external forces. Thus, absolute time in Newtonian physics is an a priori presupposition, and it is essential for the frame of reference, against which all forces are determined. Newton himself considered that in reality there might exist no absolutely equable form of motion representing this absolute time: It might not be the time of a particular clock. But still, the assumed flowing of absolute time should not be liable to any change.

However, the laws of classical mechanics, which describe the motions of massive bodies, do not distinguish a direction of absolute time: No feature of the mechanical world would change, if time were reversed. Because the basic differential equations of classical mechanics are time reversal invariant, the future development of any mechanical system is in principle derivable from its past state, and vice versa. Thus, development from past to future and from future to past are physically equivalent.

The arrow of time in thermodynamics. But what people experience in reality are often processes, which appear to be irreversibly "directed," such as the cooling of hot water or the erosion of a rock. Especially inanimate natural systems show a tendency to spontaneously evolve to equilibrium of order, energy, or temperature, where these macroscopic parameters remain approximately stable, and they never leave this state, provided no external intervention takes place. The physics to describe such processes is called *thermodynamics.* Elaborated in the mid-nineteenth century, classical thermodynamics is based on two laws, the second of which expresses the temporally asymmetric behavior of all isolated (adiabatic) systems, with the universe as the biggest of them, to approach equilibrium in due course of time. The universe thus faces *heat death,* the equilibrium state in which no energy differences remain and all physical processes come to an end, as its final fate. In order to express this fundamental law, Rudolf Clausius (1822–1888) coined the term *entropy* (from Greek *entrope,* turning toward) as a measure of dispersed and irretrievable energy that becomes unavailable for producing work. Clausius further stated that the entropy of the universe strives toward a maximum. Because entropy is at a maximum when the molecules of a system are at the same energy level, entropy can be understood as a measure of disorder. Thus, the Second Law of Thermodynamics implies the increase of disorder in due course of time, ruling out all reverse processes that could create order spontaneously within a closed system.

When James Maxwell (1831–1879) and others developed the kinetic theory of heat and gases, Ludwig Boltzmann (1844–1906) tried to reduce thermodynamics to mechanical laws and interpret the Second Law as only statistical: Systems generally develop toward states of higher entropy because such states are more probable than others. But the discussion about the statistical interpretation of thermodynamics revealed that the time reversal invariance of the mechanical laws cannot model the irreversible phenomena of macroscopic systems striving toward equilibrium. In the light of classical mechanism, the irreversible direction of time from past to future, the arrow of time as indicated by the Second Law of Thermodynamics, seems to rest on no physical ground.

Time in Special and General Theory of Relativity. The direction of time from past to future seemed to become even more illusionary when Albert Einstein's (1879–1955) Theory of Relativity succeeded in overcoming the Newtonian notion of absolute time. In his 1905 Special Theory of Relativity, Einstein stated that the time interval (and the distance) between two events depends on the observer's velocity relative to the events, while the velocity cannot exceed the speed of light.

In Einstein's theory, space and time together constitute the four-dimensional space-time, while each reference frame of an observer divides space-time differently into a temporal and a spatial component relative to its state of velocity. There is no simultaneity of events and absolute duration of time for every observer, as well as no absolute spatial distance. Still, there is an objective causal connection between events, because one event cannot interact with another instantaneously, but only mediated by forces, whose propagation speed is final and equals or is less than the speed of light. Thus temporal as well as spatial intervals between causally related events cannot become zero, and their causal relation cannot be reversed. Relativistic time still represents the order of causal chains.

Shortly after Einstein's discovery, the Russian mathematician and physicist Hermann Minkowski (1864–1909) united space and time into one four-dimensional continuum, the space-time of the so-called Minkowksi-world: "Henceforth space by itself, and time by itself, are doomed to fade away into mere shadows, and only a kind of union of the two will preserve an independent reality" (*Space and Time,* p. 75). This view of the physical world, in which no independent time exists, suggests that the world is to be envisioned as a four-dimensional *being,* rather than a *becoming* within three-dimensional space. Then, as Einstein himself stated, for a physicist "the distinction between past, present and future is only an illusion, however persistent" (quoted in Davies, 1983, p.128).

Time in quantum theory. In the Schrödinger-equation, which is the basic formula of quantum mechanics, time is not an observable, but just a parameter. Although it is time reversal invariant, in its common interpretation, the equation refers to probabilities and only allows for the determination of probabilities for certain states. When a state is measured, the Schrödinger wave-function of an object, which is derived from the Schrödinger-equation, "collapses," and a certain value for an observable is provided. Some physicists interpret this as a new notion of irreversible physical time: "The concept of becoming acquires a meaning in physics: The present, which separates the future from the past, is the moment when that which was undetermined becomes determined, and 'becoming' means the same as 'becoming determined'" (Reichenbach, p. 269).

Thus, quantum theory seems to include two concepts of time: time in the form of a classical, reversible parameter of continuous time, in which the realm of probabilities unfolds; and time in the form of the discontinuous interaction between objects, which reduces knowledge of possible states into factual, documented knowledge. Because of fundamental theoretical reasons and because of the very precise empirical data available, a dynamical description of the transition from the probability description to the factual description cannot be modeled within the theory. Thus quantum-measurement seems to establish a fundamental distinction between past and future within physics, with past and future being closely related, but without the possibility of completely deriving the factual future out of the factual past, and vice versa.

Time and biological systems

According to the Second Law of Thermodynamics, flows of energy arise far from equilibrium in order to compensate energy differences and to increase entropy. The Earth, for example, receives a constant flow of energy from the sun and dissipates energy into its cold surroundings. This energy flow establishes a direction of time, which can be identified as the source of the temporality of complex systems, biological systems in particular. Such systems are able to exploit energy flows to locally inverse the increase of entropy and to maintain themselves in a steady state far from equilibrium by functional closure against their environment. They may even develop toward states of increased order and organization, as the contingent and irreversible evolution of life on the planet shows. Biological systems can differentiate, interact, and organize themselves; they can form populations, families, and ecosystems; and, in the case of human beings, they can begin to establish history as the temporal unfolding of rational, self-conscious, and moral social agency.

The cosmological foundation of time

All manifestations of irreversible time can be seen as a consequence of the fact that the universe started off with the Big Bang in a smooth and organized state of low entropy. The interplay of its expansion with the contracting force of gravitation, which agglomerates matter into bodies of high density that start to radiate and disperse their energy into the expanding void, is responsible for the cosmos still being far away from equilibrium. It remains a matter of dispute whether cosmic time will end in a final collapse of the universe, when gravitation will have superseded expansion and reversed it into contraction, or whether expansion will go on forever, until all order and structure of the universe has been dissolved into an ever dispersing radiation field with decaying minimal fluctuations. But the expansion of the universe establishes a cosmic time, which is the origin of the large-scale arrow of time, in whose due course, in a favored niche far away from equilibrium, biological systems could evolve and develop into conscious beings, who start wondering what time is all about.

See also ENTROPY; PHYSICS, QUANTUM; RELATIVITY, GENERAL THEORY OF; RELATIVITY, SPECIAL THEORY OF; SPACE AND TIME; THERMODYNAMICS, SECOND LAW OF; TIME: RELIGIOUS AND PHILOSOPHICAL ASPECTS

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DIRK EVERS

TIME: RELIGIOUS AND PHILOSOPHICAL ASPECTS

According to Augustine of Hippo (354–430) time cannot be satisfactorily described using one single definition. In his words: "What, then, is time? If no one asks me, I know: if I wish to explain it to one that asketh, I know not" (*Confessions* 11, c. 14). The attempt to establish a conclusive definition of time ultimately leads to confusion. Time is not definable by any other concepts. Time, in its fullness, is unique and *sui generis.* This view is now generally accepted among philosophers of time. No attempt to clarify the concept of time is claimed to be more than an accentuation of some aspects of time at the expense of others. The statement of Plato (428–347 B.C.E.) that time is the "moving image of eternity" and Aristotle's (384–322 B.C.E.) suggestion that "time is the number of motion with respect to earlier and later" are no exceptions.

Time and eternity

Many philosophical and religious schools have assumed that no beginning or end can be attributed to time. For instance, in Indian thought the universe is largely conceived as undergoing repeated creation and dissolution. According to this cosmological model, each world-cycle has to be measured in terms of billions of humans years (Balslev, p. 140 ff.). Ancient Greek thought includes the even stronger idea of cyclic time according to which not only the cosmological processes but all individual destinies are repeated in every detail in time (Whitrow, p. 14 ff.). Jewish, Christian, and Muslim philosophers have had to reject this idea of cyclic time because it leaves no room for genuine progress or final salvation. Augustine, in particular, was very clear about this: "Heaven forbid, I repeat, that we should believe that. For Christ died once for our sins, but rising from the dead he dies no more, and death shall no longer have domain over him" (*De Civitate Dei* 12; vol. 4, p. 63)

Some Muslim thinkers such as al-Farabi (873–950) and Avicenna (980–1037) held that the act of creation should be conceived as atemporal and purely logical. In Judaism and Christianity, however, most philosophers have rejected this view maintaining that God's creation of the world was in fact its temporal beginning. In Judaic thought some have argued that time existed and the Torah was created before the creation of the world. This view of time would allow the notion of the universe being created *in time*. However, according to the most common view in traditional medieval philosophy, time is considered to be relational; that is, there can only be time in relation to a world of events. With this view of time, *creatio ex nihilo* means that the universe does not owe its existence to anything in the physical world, and it can only be explained by reference to something that is not a part of this temporal world. The idea of the absolute beginning of the universe does not imply any change from one state to another.

Medieval writers typically held that time itself began with creation. Thomas Aquinas (c. 1225–1274) stated this view in the following way: "The phrase about things being created in the beginning of time, means that the heavens and earth were created together with time" (*Summa Theologica* 1a, 46, 3). A similar view had been expressed earlier by the great Jewish scholar Moses Maimonides (1135–1204), according to whom the biblical statement of God's existence before the creation of the world has to be interpreted in terms of a "supposition or imagination of time" (Sorabji, p. 237). In the same vein, Aquinas stated:

> God is before the world by duration. The term 'duration' here means the priority of eternity, not of time. Or you might say that it betokens an imaginary time, not time as really existing, rather as when we speak of nothing being beyond the heavens, the term 'beyond' betokens merely an imaginary place in a picture we can form of other dimensions stretching beyond those of the body of heavens. (*Summa Theologica* 1a, 46, 1)

This means that God's eternity should not be understood as some sort of everlasting existence of the same kind as human existence. God's eternity is a dimension other than that of human time. For this reason the biblical statement that God is before creation should not be understood in a temporal way. It must be admitted, however, that it seems almost impossible to clarify this nontemporal use of *before,* although "logically before" must be a part of the meaning. But if the reality of a spiritual world is accepted, it is certainly likely there are relations that cannot be fully explained or understood by human beings.

Aquinas compared this view with the relation between the center and the circumference of a circle. The relation between the center and the circumference is the same all the way round; in a similar manner, God relates in the same way to all times.

> Furthermore, since the being of what is eternal does not pass away, eternity is present in its presentiality to any time or instant of time. We may see an example of sorts in the case of a circle. Although it is indivisible, it does not co-exist simultaneously with any other point as to position, since it is the order of position that produces the continuity of the circumference. On the other hand, the center of the circle, which is no part of the circumference, is directly opposed to any given determinate point on the circumference. Hence, whatever is found in any part of time coexists with what is eternal as being present to it, although with respect to some other time it be past or future. (*Summa contra gentiles* 1, c. 66)

The reality of the tenses

Since antiquity two images of time have been discussed: the line made up of stationary points and the flow of a river. Philosophically speaking, these images correspond to two positions: "being as timeless" and "being as temporal." The two positions can be found in early Indian thought, for instance, as held in Brahmanism and Buddhism, respectively. The different schools in the Brahmanical tradition have maintained that the ultimate being is timeless (i.e., uncaused, indestructible, beginningless, and endless). Buddhists, on the other hand, have claimed that being is instantaneous and that duration is a fiction since according to their view a thing cannot remain identical at two different instants (Balslev, p. 69 ff.).

In classical Greek thought the tension between the dynamic and the static view of time has been expressed, for example, by the Aristotelian idea of time as the number of motion with respect to earlier and later—an idea that comprises both pictures. On the one hand time is linked to motion (i.e., changes in the world), and on the other hand time can be conceived as a stationary order of events represented by numbers. This discussion is also reflected in Isaac Newton's (1642–1727) ideas of time, according to which absolute time "flows equably without relation to anything external" (*Principia,* 1687).

The basic set of concepts for the dynamic understanding of time are *past, present,* and *future.* After J. M. E. McTaggart's analysis of time in "The Unreality of Time" (1908), these concepts (i.e., the tenses) are called the *A-concepts.* They are well suited for describing the flow of time, since the present time will become past (i.e., flow into past). The basic set of concepts for the stationary understanding of time are *before, simultaneously,* and *after.* Following McTaggart, these are called the *B-concepts,* and they seem especially apt for describing the permanent and temporal order of events.

Philosophers discuss intensively which of the two conceptions is the more fundamental for the philosophical description of time. The situation can be characterized as a debate between two Kuhnian paradigms: the ideas embodied by the well-established B-theory, which were for centuries predominant in philosophical and scientific theories of time, and the rising A-theory, which in the 1950s received a fresh impetus due to the advent of the tense logic formulated by Arthur N. Prior (1914–1969). Still, many researchers do not want to embrace the A-conception. According to A-theorists, the tenses are real, whereas B-theorists consider tenses to be secondary and unreal. According to the A-theory the "Now" is real and objective, whereas the B-theories consider the "Now" to be purely subjective.

Following the ideas of Aquinas, some argue that time from God's perspective should be understood in terms of B-concepts because time is given to God in a timeless way. But it should be mentioned that Aquinas also maintained that divine knowledge can be transformed into the temporal dimension by means of prophecies. It seems that Aquinas was suggesting a distinction between time as it is for temporal beings such as humans and time as it is for God, who is eternal. However, this does not answer the important question: Are the tenses real? Is the "Now" real?

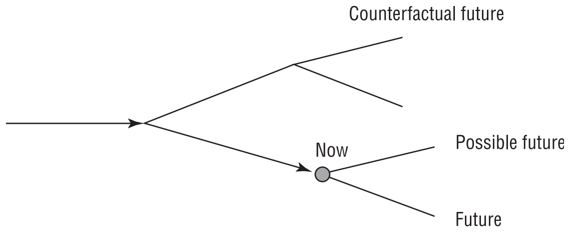
Most writers in Christian philosophy defend the view that "my Now," "my present choice," or "my present awareness" actually represents something real. This will lead most writers in Christian philosophy to the A-theory. They normally find it obvious that the concept of time has to be related to the human mind. Therefore it becomes more natural to describe time by means of tenses (past, present, and future) than by means of instants (dates, clock-time, etc.). With tenses, one can express that the past is forever lost and the future is not yet here. Without these ideas one cannot hope to grasp the idea of the passing of time. Phenomena such as memory, experience, observation, anticipation, and hope are all essential for the way time is understood. Notions of past and future time, the interpretation of the past, and expectations of the future are all interwoven in the human mind. Nevertheless, A-theorists claim that the distinction between past and future is objective, or at least intersubjective.

Human freedom and divine foreknowledge

During the Middle Ages logicians felt that they had something important to offer with regard to solving fundamental questions in theology. The most important question of that kind was the problem of the contingent future. The intellectuals of the Middle Ages saw the problem as intimately connected with the relation between two fundamental Christian dogmas: human freedom and God's omniscience. God's omniscience is assumed to comprise knowledge of future choices to be made by human beings but apparently gives rise to a straightforward argument from divine foreknowledge to necessity of the future: If God already knows the decision one will make tomorrow, then there is already now an inevitable truth about one's choice tomorrow. Hence, there seems to be no basis for the claim that one has a free choice, a conclusion that violates the dogma of human freedom. The argument proceeds in two phases: first from divine foreknowledge to necessity of the future, and from that argument to the subsequent conclusion that there can be no real human freedom of choice. The problem obviously bears on the theological task of clarifying questions such as "In which way can God know the future?" or "What is to be understood by *free will* and *freedom of choice*?" In his treatise *De eventu futurorum,* Richard of Lavenham (c. 1380) suggested a systematical overview of basic approaches to the problem: If two dogmas are seemingly contradictory, then one can solve the problem by denying one of the dogmas or by showing that the apparent contradiction is not real (Øhrstrøm and Hasle, p. 87 ff.).

Denial of the dogma of human freedom leads to fatalism (first solution). Denial of the dogma of God's foreknowledge can either be based on the claim that God does not know the truth about the future (second solution) or the assumption that there is no truth about the contingent future since nothing has yet been decided (third solution). One can alternatively demonstrate that the two dogmas, rightly understood, can be united in a consistent way (fourth solution). The first two solutions were seen as contrary to Christian belief, according to which humans are free at least to a certain degree, and according to which God knows all truth. Peter Aureole (c.1280–1322) is notable among the defenders of the third solution. He claimed that neither the statement "the Antichrist will come" nor the statement "the Antichrist will not come" is true, whereas the disjunction of the two statements is actually true. From that point of view, one can naturally claim that the dogma of God's omniscience is still tenable, even if God does not know if the Antichrist will come or not. God knows all the truths given and cannot know if the Antichrist will come due to the simple reason that no truth about the Antichrist's future decisions yet exists. In modern philosophy, this third solution has been defended by Prior and by Charles Sanders Peirce (1839–1914). This idea of a totally open future is often illustrated using a branching time model:

The Peirce Model



SOURCE: Courtesy of author.

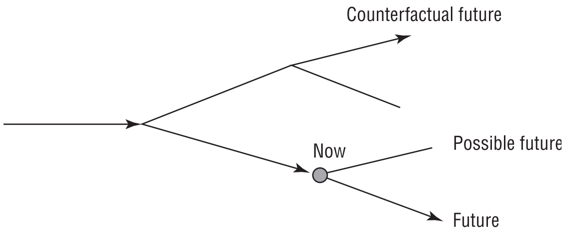
The Peirce Model

The central feature of the fourth solution is its use of the notion of a "true future" among a number of possible futures. This solution was originally formulated by William of Ockham (c. 1284–1347). He discussed the problem of divine foreknowledge and human freedom in his work *Tractatus de praedestinatione et de futuris contingentibus.* He asserted that God knows all future contingents, but he also maintained that human beings can choose between alternative possibilities. Ockham was aware that considerations on the communication from God to human beings are essential. God can communicate the truth about the future to human beings. Nevertheless, according to Ockham, divine knowledge regarding future contingents does not imply that they are necessary. As an example, Ockham considered the prophecy of Jonah: "Yet forty days, and Nineveh shall be overthrown" (Jonah 3:4). This prophecy is a communication from God regarding the future. Therefore, it might seem to follow that when this prophecy has been proclaimed, then the future destruction of Nineveh is necessary. But Ockham did not accept that. Instead, he made room for human freedom in the face of true prophecies by assuming that "all prophecies about future contingents were conditionals" (Ockham, p. 44). So, according to Ockham, the prophecy of Jonah must be understood as presupposing the condition "unless the citizens of Nineveh repent." Obviously, this is exactly how the citizens of Nineveh understood the statement of Jonah.

Ockham realized that the revelation of the future by means of an unconditional statement, communicated from God to the prophet, is incompatible with the contingency of the prophecy. If God reveals the future by means of unconditional statements, then the future is inevitable, since the divine revelation must be true. The concept of divine communication (revelation) must be taken into consideration, if the belief in divine foreknowledge is to be compatible with the belief in the freedom of human actions. However, Ockham had to admit that it is impossible to express clearly the way in which God knows future contingents. He also had to conclude that, in general, divine knowledge about the contingent future is inaccessible. God is able to communicate the truth about the future to human beings, but if God reveals the truth about the future by means of unconditional statements, the future statements cannot be contingent anymore. Hence, God's unconditional foreknowledge regarding future contingents is in principle not revealed, whereas conditionals can be communicated to the prophets. Even so, that part of divine foreknowledge about future contingents, which is not revealed, must also be considered as true according to Ockham.

It can be argued that Anselm (1033/34–1109) had suggested long before Ockham a similar solution to the problem of divine foreknowledge and human freedom. Much later, Gottfried Wilhelm Leibniz (1646–1716) worked out a metaphysics of time, which from a systematical point of view is similar to the thoughts of Anselm and Ockham. The Ockhamistic solution can be illustrated using the modern notion of "branching time":

The Ockham Model



SOURCE: Courtesy of author.

The Ockham Model

From a theological point of view this model presupposes what has been called *middle knowledge,* which is God's knowledge of what every possible free creature would do under any possible set of circumstances (Craig, p. 127 ff.).

Toward a common language for the study of time

In order to gain more knowledge about the temporal aspects of reality, time has to be studied within many different strands of science. If such studies are to lead to a deeper understanding of time itself, various disciplines have to be brought together in the hope that their findings may form a new synthesis, even though one should not expect any ultimate answer regarding the question of the nature of time. If a synthesis is to succeed, a common language for the discussion of time has to be established.

The twentieth century has seen a most striking rediscovery of the importance of time and tense. This is first and foremost due to the work of Arthur Prior, who was deeply inspired by his studies in ancient and medieval logic. During the 1950s and 1960s Prior laid out the foundation of tense logic and showed that this important discipline was intimately connected with modal logic. He revived the medieval attempt at formulating a temporal logic corresponding to natural language. In doing so, he also used his symbolic formalism for investigating the ideas put forward by these logicians. Prior argued that temporal logic is fundamental for understanding and describing the world in which human beings live. He regarded tense and modal logic as particularly relevant to a number of important theological as well as philosophical problems. The main parts of temporal logic have been developed using mathematical symbolism and calculus, but nevertheless it has first and foremost been a philosophical enterprise.

According to Augustine, all humans have a tacit knowledge of what time is, even though they cannot define time. In a sense, the endeavor of temporal logic is to study some manifestations of this tacit knowledge. The concept of time can in fact be studied using temporal logic. It seems likely that Prior's tense logic may become a crucial part of a common language for the discussion of time.

In his temporal logic Prior, among many other things, took the uncertainty of the future into account. This means that it is assumed that no description of the future can be complete because it must be discussed in terms of open statements and ambiguous expressions. The reason is that some future events cannot be specified fully and satisfactorily in terms of the present vocabulary. In his temporal logic Prior suggested a notion of *unstatability.* According to this idea, the language needed for a proper description of the temporal world is growing, and present events can be described more fully than was possible earlier when the events were still part of the future.

See also T = 0; TIME: PHYSICAL AND BIOLOGICAL ASPECTS

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PETER ØHRSTRØM

TOP-DOWN CAUSATION

See DOWNWARD CAUSATION

TRANSCENDENCE

The term *transcendence,* from the Latin *transcendere* (to climb up), means to go beyond, surpass, or rise above, particularly what is given in personal experience. In theology, transcendence is associated with the beyondness and holiness of God, in the sense of the existence of God being prior to the physical cosmos and exhalted above it. Referring to divine ascent beyond the world, transcendence is frequently contrasted with immanence, the presence of God in the world. Historically, deism emphasized total transcendence of the world while pantheism stressed the total immanence of God in the world. Most theistic traditions seek a balance between the two.

See also DEISM; GOD; HUMAN NATURE, RELIGIOUS AND PHILOSOPHICAL ASPECTS; IMMANENCE; PANTHEISM

ERNEST SIMMONS

TRANSMIGRATION

The term *transmigration,* from the Latin *transmigrare* (to migrate across or over), means to pass from one condition, place, or body to another. Transmigration is usually identified with the Greek word *metempsychosis* (change of soul), the "transmigration of souls" drawing on the Greek Orphic mysteries. In South Asian religions, transmigration is related to the karmic cycle where one's moral action determines the condition of the soul and the quality of its rebirth. In Hinduism, the cycle of rebirth is eternal unless the soul is liberated (*moksha*) by knowledge or arduous effort (Yoga). In Buddhism the soul and transmigration are ultimately illusory (*maya*), being passing emergents from *samsara,* the eternal, undifferentiated stream of being.

See also KARMA; LIFE AFTER DEATH

ERNEST SIMMONS

TRUTH, THEORIES OF

The question of truth is inherent in human rationality. A core feature of rationality is self-reflection in the sense that we can critically reflect upon how we see the world. In the question of truth our relation to reality is called into question, and the pursuit of truth is therefore pivotal to both science and religion.

When we are asking for a theory of truth, we take a step back and focus on our conception of truth. The first thing to be noted is that we use the word *true* as an adjective for various things: A statement can be true, but so can a friend or an act of friendship, or a democracy. In the latter cases we may substitute *real* for *true*: A true friend is a real friend whom we can count on. But if the sentence "She is a true friend" is true, it is so in a sense where we cannot substitute *real* for *true.* This indicates that a theory of truth deals with mental acts (e.g., beliefs) or statements (judgments, propositions) as truth bearers. Mental acts or statements are about something. A theory of truth thus operates at the level where we relate to something, and relate in such way that we make truth claims about what we relate to (i.e., claims as to what it is and how it is). The key issue for a theory of truth is the relation between beliefs or statements that can be true or false, and that which these beliefs or statements are about. We can then distinguish between the following types of truth theories: the correspondence theory, the coherence theory, and pragmatic theories.

Correspondence theory of truth

According to a correspondence theory of truth, the truth relation is a correspondence between a statement and a fact. A theory of this kind reflects a commonsense idea of truth to the effect that a statement is true if it corresponds to how things actually are. This is captured in the classic formulation of the correspondence theory in Aristotle (384–322 B.C.E.): "To say of what is that it is not, or of what is not that it is, is false, while to say of what is that it is, and of what is not that it is not, is true" (Aristotle, 1011b26f). Thus, *truth* means agreement with reality. However, a statement cannot correspond to a thing or an event. In order to ascertain whether a statement is true or false we need to know what it is about, that is, what the thing or the event in question is. What makes a statement *p* (e.g., "He was late") true is the *fact* of *p* (i.e., that he actually was late). Correspondence is thus correlation between statements and facts. It need not be congruence, however, in the sense that the structure of the statement somehow reflects the structure of the fact.

But this does not solve the problem of explicating what it is that statements correspond to. We do not have two separate entities, statements, and facts. It might be argued that facts are what true statements state, not what they are about. And if we are going to determine what the fact is to which the statement corresponds—in order to compare statement and fact—then we must make another statement. Thus, the relation between statements and reality can only be determined by other statements.

Coherence theory of truth

A coherence theory of truth seeks to meet this problem by transforming correspondence between statement and fact into coherence between statements. A statement or belief is true to the degree it coheres with other accepted statements or beliefs related to it, or to be more precise, if it fits into the most coherent set or system of statements or beliefs. What is required for a set of statements or beliefs to be coherent is internal consistency, or even mutual entailment between the statements or beliefs in question. To this can be added the further requirement that the system not only is coherent, but also gives the most complete picture of the world. Thus, the argument for a coherence theory not only is that a statement can only be compared to other statements, but also that a statement or a belief never is without context: It presupposes other statements in order to be true, and it does so because a thing is what it is due to its relations to other things. Consequently, a coherence theory of truth often is linked to a metaphysics according to which reality basically is a coherent system. But the context can also be construed as a system of interpretations that we presuppose when making a statement. We can only compare interpretations with other interpretations. A coherence theory thus favors an antirealist ontology to the effect that there is no mind-independent or extralinguistic reality.

The coherence solution however engenders problems of its own. First, standard versions of the coherence theory confuse the meaning of truth (the definition) with the criterion of truth (the test). Second, it seems possible to have two internally coherent, but mutually inconsistent sets of beliefs concerning the same reality. The further requirement that a coherent system must also give the most complete picture of the world implies that we should be able to compare competing sets of beliefs as interpretations of the same world. Third, if a statement is true when it coheres with what we already accept to be true, how do we decide the truth of these other statements or beliefs, upon which the first statement depends? And how is our view of reality changed?

Pragmatic theories of truth

A pragmatic theory of truth takes a step further by focusing on the social context of understanding. One version is a consensus theory that translates the meaning of truth into the context of argumentation. It is not sufficient to say that a statement is true if it coheres with our accepted views. A stronger condition is that a statement is true if it is accepted by the most informed participants or by everyone with sufficient relevant experiences to judge it. But if truth amounts to what the most informed participants or everyone sufficiently experienced agree upon, the question is how to decide who are the most informed participants or when we are sufficiently experienced. In order to avoid this problem, the criterion of consensus can be made both stronger and more open-ended: If truth is what everybody will ultimately agree upon, a theory of consensus can place some stronger conditions on what is meant by *ultimately.*

Jürgen Habermas (1929–) reformulates the consensus theory as a discourse theory: The meaning of truth is "warranted assertibility." Statements are true if their truth claims are warranted in a discourse in which we only enter by presupposing an ideal situation of communication where no participant is in a privileged position. Truth is thus defined in the context of argumentation in which we meet various or even conflicting truth claims that are open to discussion in a discourse. But if the meaning of truth is defined by the procedure of argumentation, this procedure cannot recur to the concept of truth. If truth is translated into the consensus to be reached, this consensus cannot in turn be measured by truth. The argumentation in a discourse about truth claims, however, is not about consensus but about truth. If it aims at consensus, it is a consensus concerning what the truth is. Consequently, there remains a normative dimension of truth, which in Habermas is translated into the ideal situation of communication.

A second version of a pragmatic theory of truth is an instrumentalist theory that measures the truth of beliefs or statements by their consequences: "That which guides us truly is true—demonstrated capacity for such guidance is precisely what is meant by truth. . . . The hypothesis that works is the true one; and truth is an abstract noun applied to the collection of cases, actual, foreseen and desired, that receive confirmation in their works and consequences" (Dewey, p. 156–157). The problem here is how to decide what *truly* means. The reference to consequences is in need of qualification as to which consequences would meet the requirement of guiding us truly. In fact, an instrumentalist theory substitutes utility for truth.

As an alternative to an instrumentalist theory ("The truth is what works"), the central pragmatist idea can be reformulated in a performative theory of truth that focuses on what we are doing when we take something to be true. This is outlined by Robert B. Brandom (1950–) in a model that emphasizes the act of calling something true rather than the descriptive content of truth statements. It further gives an account of that act in terms of a normative attitude: Taking some claim to be true is committing oneself to it. Endorsing a truth claim is understood as adopting it as a guide to action, and the correctness of adopting it can be measured by the success of the actions it guides (involving here what Brandom calls "stereotypical" pragmatism). Once we have understood acts of "taking-true" according to this model, we have "understood all there is to understand about truth." This means that truth "is treated, not as a property independent of our attitudes, to which they must eventually answer, but rather as a creature of taking-true or treating-as-true" (Brandom, p. 287). This performative analysis of truth talk in terms of a theory of "taking-true" can be combined with a redundancy theory of truth: When we state "It is true that *p,*" we only make explicit the claim implicit in stating *p.* In calling the statement *p* true, we are not describing a property of that statement. We are doing something—we are committing ourselves.

A pragmatic theory of truth takes as its point of departure that there is no absolute or universal truth at our disposal. Still, as we have seen, a pragmatic theory can maintain and seek to account for the normative dimension of truth. It here differs from a radical instrumentalist theory according to which truth is a fiction in the sense of human construction. According to Friedrich Nietzsche (1844–1900), truth is not something to be found but something to be created. Although, in Nietzsche, truth is itself illusion, fiction, or construction, there still seems to be a normative dimension unaccounted for in his unmasking of illusions.

Truth in religion

Coherence and pragmatic theories of truth derive much of their plausibility from the ambition to avoid the problems facing a correspondence theory. However, the question is whether we can do without a strong normative concept of truth that reflects the experience of a reality not corresponding to our beliefs or interpretations. Truth as an open question implies a strong concept of truth in the sense that we ourselves have to experience whether our beliefs are true or not. The key issue in theories of truth can be reformulated as the relation between our cognitive attitudes and reality. The challenge facing us is to account both for the fact that we do not have access to a reality outside of our attitudes or our interpretations of reality, and for the normative dimension of truth. The line of argument has led from descriptive attitudes that consider the world from outside to cognitive attitudes embedded in social practices in which we partake in the reality we are talking about. Truth claims can be implicit in nondescriptive attitudes.

When we are talking about the world we are not only describing how things are, but we are relating to the world in various ways.

That truth is a question of how we relate to the world is brought out in what can be called an existential conception of truth, which should not be confused with an existentialist or subjectivist reduction of truth. According to Søren Kierkegaard (1813–1855), "the truth is only for the individual in that he produces it in action," but in the same vein it is stated that "the truth makes a human being free" (1980, p. 138). The dictum that "subjectivity is truth" (Kierkegaard, 1992, p. 240) does not mean that each of us freely chooses what should count as the truth. The point is conversely that subjectivity itself is to be determined by the truth. Taking something to be true implies that it should determine the way we relate to ourselves and to others.

This leads to the issue of truth in religion. The truth question is basic not only to the rational inquiry into nature, but also to the understanding of religion. Indeed, the issue of rationality and religion turns on the question of truth. What happens when the question of truth is seen within the context of religion? First, the tension between uncertainty (implicit in asking the question) and certainty (in answering it) is intensified: What is meant by the truth in view of conflicting truth claims? Second, religion represents a double possibility. It can suspend the truth question by giving an answer to it that is not open for discussion, but it can also reopen the truth question by calling our attitudes and self-understanding into question. Third, in religion, the relation between cognitive attitudes, on the one hand, and volitional and affective attitudes on the other, and between attitudes and action, is complicated. To believe in the truth implies that we understand ourselves in the light of the truth, which means that it should form our life. Fourth, what religion can do is reverse the perspective: The truth question is not only a question for us to decide, but also calls into question how we relate to the world. When religion speaks of the truth, it is also implied that truth is not at our disposal, but conversely questions us: What is the truth about us? The truth question is also disturbing when it calls into question who we, the subjects of the question, are.

See also IDEALISM; PLATO; PRAGMATISM; REALISM

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ARNE GRØN

TURING TEST

The Turing Test was proposed by computer pioneer Alan M. Turing (1912–1954) to determine whether a computer program is intelligent. This modern interpretation of the so-called imitation game is based on a setup where a person, a computer, and an interrogator are in three separate rooms and connected via computer terminals. The task of the interrogator is to figure out by asking questions which of the two connected terminals is operated by the human and which is the test computer. The computer is considered to be intelligent if the interrogator fails to determine its identity.

The Turing Test is recognized as a critical test for computer intelligence and, as of 2002, had not been passed by any computer.

See also ARTIFICIAL INTELLIGENCE; THINKING MACHINES

THIEMO KRINK

TWO BOOKS

Permeating the Western Christian tradition of natural theology is a metaphor expressing the belief that God is revealed in a complementary pair of sources: the book of scripture and the book of nature. The idea of nature as a book was used by early modern writers as shorthand for the design argument for God's existence. Thomas Browne (1605–1682), for example, wrote, "There are two books from whence I collect my divinity: besides that written one of God, another of his servant, nature, that universal and public manuscript that lies expansed unto the eyes of all" (*Religio Medici* I.16).

Origins of the metaphor

The metaphor was born at the confluence of a number of streams: the common human experience of the transcendent, the conviction of the reality of divine-human communication, and the Western fascination for books as repositories of knowledge. The conviction that God is made known through divine works is celebrated in *Psalm* 19, and *Wisdom* 11: 6–9 articulates the idea that even gentiles who have not enjoyed the benefit of revelation are without excuse for their unbelief, a tradition persisting at least until the time of John Calvin (1509–1564). The New Testament *locus classicus* for the natural knowledge of God is the Pauline declaration, "For what can be known about God is plain to them, because God has shown it to them. Ever since the creation of the world his invisible nature, namely, his eternal power and deity, has been clearly perceived in the things that have been made" (*Romans* 1:19–20).

The elements of what would become the "book of nature" metaphor are scattered throughout Patristic literature. Justin Martyr (c. 100–165) built his second-century apologetic upon the Stoic idea of the *logos spermatikos,* arguing that the world is permeated by seeds of the divine word (*Second Apology* VIII), and Irenaeus (c. 130–200) provided the two essential ingredients of the theme in the works and the word of God (*Adversus haereses,* Book I, ch. 20). Tertullian (c. 160–225) regarded the works of God as an important revelatory counterpart to the Bible (*Adversus Marcionem,* Book II, ch. 3). For Augustine of Hippo (354–430) the book of the heavens provided milk for the spiritually immature (*Confessions,* Book XIII, ch. 18.23, 26). The closest thing to a formal Patristic statement of the metaphor of "the book of nature" may be found in John Chrysostom's (c. 347–407) *Homilies to the people of Antioch,* in which he declared that nature serves the function of a book of revelation: "Upon this volume the unlearned, as well as the wise man, shall be able to look, and wherever any one may chance to come, there looking upwards towards the heavens, he will receive a sufficient lesson from the view of them. . . ." (*Homily* IX. 5).

The metaphor became firmly established in the Middle Ages, expressing a mature binary epistemology of revelation. Alain of Lille (c. 1128–1203) held every created thing to be like a book; Hugh of Saint Victor (1096–1142) regarded both the creation and the incarnation as "books" of God, comparing Christ—as primary revelation—to a book. Bonaventure (c. 1217–1274) suggested that there are three volumes: sensible creatures are "a book with writing front and back," spiritual creatures are "a scroll written from within," and scripture is "a scroll written within and without" (*Collations on the Hexaemeron* 12.14–17). For Thomas Aquinas (c. 1225–1274) the first element of the threefold knowledge of divine things is "an ascent through creatures to the knowledge of God by the natural light of reason" (*Summa Contra Gentiles,* IV.1.3). For the poet Dante Alighieri (1265–1321), the godhead is the book in which all the loose pages scattered throughout the universe will eschatologically be bound in one volume (*Paradiso* XXXIII). Raymond of Sabunde (d. 1436) gave the metaphor its fullest medieval articulation in his *Theologia Naturalis sive Liber Creaturarum.* He regarded every created thing as a letter written by the finger of God, and human beings as the first letters of this book. His work attracted the attention of the censors, however, because of his incautious opinion that the book of nature is more accurate than the Bible, and his assertion of the preeminent importance of natural knowledge; it was placed on the Index (the official list of books prohibited by the Roman Catholic church) in 1595.

Early modern variations on the theme

The "book of nature" enjoyed its greatest currency in the early modern period. The emphasis of the Reformers on the literal sense of scripture cut through the profusion of "meanings" and "signatures" found by medieval scholars in nature and reinforced the idea of there being two books. However, the book of nature was clearly subordinate to biblical revelation in Calvin's theology, which held scripture to be a necessary corrective to the deficiencies of nature (*Institutes* I.6.1). The Reformed tradition retained this Calvinist interpretation of the two books in the *Belgic Confession* adopted by the Dutch Reformed Church. In contrast, Paracelsus (1493–1541) suggested an empirical approach: Whereas scripture was to be explored through its letters, the book of nature had to be read by going from land to land, since every country was a different page.

The metaphor was affected in the seventeenth century by both the elaboration of natural theology and the development of the sciences in novel empirical and theoretical directions. Pierre Gassendi (1592–1655) saw purpose in all of nature and suggested that if René Descartes (1596–1650) wanted to prove the existence of God, he ought to abandon reason and look around him, and that the two books were not to be kept on separate shelves. Although Francis Bacon (1561–1626) seems in practice to have kept the two books distinct, he articulated their essential complementarity:

> The scriptures reveal to us the will of God; and the book of the creatures expresses the divine power; whereof the latter is a key unto the former: not only opening our understanding to conceive the true sense of the scriptures, by the general notions of reason and rules of speech; but chiefly opening our belief, in drawing us into a due meditation of the omnipotency of God, which is chiefly signed and engraven upon his works. (*The Advancement of Learning* VI, 16)

Bacon set the tone for the seventeenth-century scientific enterprise in his redirection of the "two books" metaphor toward the improvement of the human estate.

Galileo Galilei (1564–1642) argued that the book of nature is written in the language of mathematics, not only implying that mathematics is the sublimest expression of the divine word, but *de facto* restricting its full comprehension to those who are appropriately educated:

> And to prohibit the whole science [of astronomy] would be but to censure a hundred passages of holy Scripture which teach us that the glory and greatness of Almighty God are marvelously discerned in all his works and divinely read in the open book of heaven. . . . Within its pages are couched mysteries so profound and concepts so sublime that the vigils, labors, and studies of hundreds upon hundreds of the most acute minds have still not pierced them, even after continual investigations for thousands of years. (*Letter to Grand Duchess Christina*)

Galileo's famous dictum that scripture teaches "how one goes to heaven, not how heaven goes" should be interpreted in light of his conviction of the complementarity of the two books.

The metaphor flourished in the natural theological climate of seventeenth-century England, particularly in the "physico-theology" of the Boyle Lectures. But its two terms were not always held in comfortable balance. The dissenting theologian Richard Baxter (1615–1691), for example, argued that "nature was a 'hard book' which few could understand, and that it was therefore safer to rely more heavily on Scripture" (*The Reasons for the Christian Religion,* 1667). In contrast, Isaac Newton (1642–1727) saw nature as perhaps more truly the source of divine revelation than the Bible, although he spent decades of his life investigating the prophetic books. Frank Manuel, in *The Religion of Isaac Newton* (1974), argues that in virtually abolishing the distinction between the two books, which Newton revered as separate expressions of the same divine meaning, Newton was attempting to keep science sacred and to reveal scientific rationality in what was once a purely sacral realm, namely, biblical prophecy. By the early eighteenth century there was a significant faction within the Royal Society opposed to any mention of scripture in a scientific context.

Decline and survival

Although the metaphor of the book of nature persisted vigorously into the nineteenth century, various movements began to undermine its cogency. The Enlightenment critiques of David Hume (1711–1776) and Immanuel Kant (1724–1804) undermined the project of natural theology in broad strokes, and the Deist movement challenged the uniqueness of the Christian revelation. Thomas Paine (1737–1809) asked defiantly, "Do we want to know what God is? Search not the book called the Scripture, which any human hand might make, but the Scripture, called the creation" (*The Age of Reason,* 1794).

Other trends exercised equally damaging effects. The revolutions in geology and biology eroded longstanding traditions of a young Earth and an immutable creation, and wore away the bedrock beneath a coherent "book of nature" temporally coextensive with the "book of scripture." Charles Babbage (1791–1871) advanced a view in his *Ninth Bridgewater Treatise* (1838) that seems to verge almost on asserting the superfluity of scriptural revelation in light of the book of nature. Parallel to the "historicization" of geology and biology, the development of an historical critical approach to study of the scripture affected the "two books" theme no less, challenging profoundly rooted tradition about the Bible constituting an integral and timeless record of the Word of God.

Despite the developments outlined above, the metaphor continued to thrive during the nineteenth century among both conservative anti-Darwinians and more liberal thinkers who enthusiastically adopted the principles and discoveries of contemporary science. A decade after the publication of Darwin's *Origin of Species* in 1859, Herbert Morris (1818–1897) argued that scripture and nature represent respectively the verbal and the pictorial aspects of divine wisdom, correlating the "inspired record of creation" with contemporary science (*Science and the Bible,* 1871). Paul Chadbourne (1823–1883) regarded nature as an unchangeable record, written in the language of the sciences of which geology comprised the most clearly comprehended volume (*Nature and the Bible from the Same Author,* 1870). Geologist Joseph Le Conte (1823–1901) declared that "the whole object of science is to construct the theology of the divine revelation in nature." Although quite clear about the limits of science as a commentary on the book of scripture, he held that "of these two books, nature is the elder born, and in some sense, at least, may be considered the more comprehensive and perfect" (*Religion and Science,* 1902).

The innovations in hermeneutics and science pushed the more religiously conservative wings of society in a precritical direction of maintaining verbal inerrancy and defending the ancient understanding of Earth history. The metaphor of the "book of nature" would gain weight as one of the cornerstones of their position, thriving in evangelical and fundamentalist-creationist circles right through the end of the twentieth century.

However, in both liberal and neo-orthodox theology the metaphor of "God's two books" entered into steady decline after 1900. Parallel to the development of historical geology and biblical criticism was the erosion of confidence that one can easily interpret natural processes teleologically, as William Paley (1743–1805) had once argued. The discovery of extinction in the fossil record challenged the ancient assumption of the immutability of species, rendering it increasingly difficult to read the "book of nature" as self-evidently revealing the divine plan, or at least a plan worthy of admiration. Additionally, the metamorphosis of "natural philosophy" and "natural history" into the variety of sciences as they are known today undercut both terms in the metaphor of "God's two books." As each new scientific discipline developed its own sphere of study, the "nature" underlying the "book of nature" lost its metaphorical coherence, and the replacement of science as commentary on authoritative texts by the empirical investigation of the natural world essentially removed the "book" from the "book of nature." Finally, the gradual recognition over the last two centuries that the human community embraces a plurality of religious faiths has had the effect of relativizing the Bible as a source of revelation. The "two books" metaphor truly functions only if the claim can be defended that the Bible is *the* book of scripture.

The complex theme of the "book of nature" has enjoyed a long and convoluted history. For nearly two millennia the metaphor variously framed, constituted, negated, or otherwise reflected the relationship between the two human institutions now referred to as science and religion. If it appears to be a less convincing rhetorical device in postmodernity, understanding the lifecycle of the metaphor can reveal a great deal about the conversation between religion and science.

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PETER M. J. HESS

U

UFO

The modern UFO phenomenon began in 1947 with the eyewitness account of pilot Kenneth Arnold of nine flying disks near Mount Rainier in Washington. The newspapers called them *flying saucers.* UFO is the more technical term, standing for *unidentified flying object.* A sighting acquires this designation only after scientific attempts to identify it as a star, meteor, balloon, aircraft, or hallucination have failed. UFO refers to what is unidentified after attempts to identify it.

Types of sightings

As a phenomenon of perception, scholars study both the perceiver and the perceived, both the UFO and its witness. Sightings are classified as: (1) daylight disks; (2) nocturnal lights; (3) radar sightings or combinations of radar and visual sightings; (4) close encounters of the first kind, when the witness is within 500 feet of the object or craft; (5) close encounters of the second kind, when physical traces of the object or craft are left for investigation; and (6) close encounters of the third kind, when witnesses claim to encounter beings connected to a flying craft. Investigators give higher credibility to multiple witness sightings, especially when witnesses are independent of one another. Such categorizing is itself part of the UFO phenomenon, reflecting the scientific attitude investigators take to their work.

Government evaluations of UFOs

Seldom has the academic community taken up the subject of UFOs for research and analysis. The U.S. government sponsored various investigative programs from 1947 through 1969 such as Project Sign and Project Bluebook; but the government's interest was primarily national defense. Convinced that UFOs provided no threat to national security, these efforts deliberately sought to debunk public claims to UFO sightings in an attempt to reduce the quantity of reports various governmental agencies would need to process.

From 1967 to 1969, Edward U. Condon at the University of Colorado conducted a federally funded study, *Final Report of the Scientific Study of Unidentified Flying Objects.* What became known as the Condon Report concluded that "nothing has come from the study of UFOs" that would warrant "further extensive study." On this basis, the U.S. Air Force dropped Project Bluebook and ceased collecting data. J. Allen Hynek, the principal astronomer and scientific debunker for Project Bluebook, converted, so to speak, and began his own private research organization, the Center for UFO Studies at Northwestern University.

Social and cultural aspects

As a social phenomenon, since their first appearance following the Second World War, two elements have been present in public perception: an association of UFOs with the possibility of extraterrestrial intelligent life, and vociferous criticism of the U.S. government for allegedly withholding vital secrets from its citizens and the world. In addition, UFO research organizations, such as the Mutual UFO Network (MUFON), have been established, and new religious movements such as Heaven's

Gate, the UNARIUS Society, the Aetherius Society, and the Raelians see great significance in UFOs.

The UFO phenomenon is frequently confused with science fiction, although no relationship exists between the two, which followed separate paths in the first decades after the Second World War. Science fiction literature and films generally depicted extraterrestrials as enemies, invaders threatening earth and against whom earthlings would have to unite in self-defense. In contrast, within the UFO community extraterrestrials were viewed as either benign or, in many cases, as benevolent, as celestial saviors coming to Earth to rescue humanity from self-destruction. Two notable Hollywood films portrayed the UFO experience as UFO believers interpret it: Robert Wise's *The Day the Earth Stood Still* (1951) and Steven Spielberg's *Close Encounters of the Third Kind* (1977).

For the first forty years of the phenomenon the space visitors were pictured as benign or benevolent. Then in the late 1980s reports were published of abductions in which the UFO abductors behaved much like abusers. Attributed to them were plots to impregnate earth women with extraterrestrial sperm to raise a hybrid race that unites heaven and Earth. After a decade of such reports, subsequent interviews of alleged abductees revealed a shift in interpretation. Abductees who originally reported a sense of violation by their space captors began to interpret extraterrestrial motives as spiritually beneficial and healing.

As a cultural phenomenon, UFOs have picked up surface and subtle sublimated meanings. On the surface, they are strange objects seen in the sky. Below the surface, UFOs function symbolically to bear religious meaning in a secular culture imbued by natural science and secular self-understanding. Sublimated religious meaning expresses itself in at least four forms: *transcendence, omniscience, perfection,* and *redemption*.

Transcendence. In many archaic religions the sky was a natural symbol of transcendence, and in the modern world outer space has replaced the sky in this role. Sky gods were powerful gods, wielding thunderbolts and scorching the earth with a blazing hot sun. With airplanes and weather reports mastering the sky, modern people have lost the sense of celestial transcendence. The apparent infinity of outer space, however, revives this lost spiritual sensibility. Because UFOs are seen in the sky and associated with outer space, they allegedly have mastered travel over unfathomable distances. They come from beyond, a physical beyond that easily slips over to become a spiritual beyond.

Omniscience. The worldview of modern society includes evolutionary theory in its self-understanding, and when the question of extraterrestrial life is raised, evolution is exported to outer space. Although biologists see no scientific basis for progress in biological evolution on earth, the popular mind identifies evolution with technological advance. When projected onto possible beings in space, they are thought to be more "advanced" than earthlings. Their technological knowledge is superior. In UFO religious groups, extraterrestrials are said to have gained telepathic powers so they can read earthlings' minds, a quality previously attributed to angels.

Perfection. Again, projecting evolution understood as progress infers that the extraterrestrials who have evolved for a very long time not only have perfected technology but have also perfected bodily health and social morality. They have conquered disease, live for extraordinarily long periods, and, most importantly, they are pictured as living in peace, especially peace with nuclear power and without ecological deterioration.

Redemption. Having achieved transcendent travel, ultimate technological knowledge, and social perfection, the space travelers are in a position to save the earth from the threat of nuclear war and ecological disaster. The extraterrestrials are Gnostic redeemers because, as new religious groups forming around UFO belief testify, their mission is to teach citizens of Earth to pull together into a single planetary society that lives in peace, prosperity, and harmony with nature. This entire belief structure is a modern myth—what Carl Jung called a "myth of things seen in the sky."

The UFO phenomenon, which includes both believers and what is believed, provides a gate into understanding the dynamics of a culture totally imbued with natural science, so much so that religious sensibilities must make their appearance in sublimated form.

See also EXOBIOLOGY; EXTRATERRESTRIAL LIFE

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TED PETERS

UNPREDICTABILITY

The term *unpredictability* refers to the failure of predicting future events out of a given state of affairs with the help of scientific laws, which relate effects to causes. By establishing fundamental unpredictability within the basis of scientific description itself, quantum theory and the theory of complex systems have undermined a central conviction of classical physics namely, that precise predictability is in principle achievable. While quantum theory seems to point to a fundamental ontological indeterminism, unpredictability entailed by the theory of complex systems can be reduced to deterministic laws and is routed in the sensitivity of complex systems to minimal deviations of their initial conditions.

See also CHAOS, QUANTUM; CHAOS THEORY; PHYSICS, QUANTUM

DIRK EVERS

UPWARD CAUSATION

When the direction of causal influence extends from 'higher' levels of reality (say, those above the level of physics) down to 'lower' levels of reality, we speak of *downward causation.* The various sciences are commonly, though not uncontroversially, assumed to stand in some hierarchical relationship to each other. Physics is considered the basic science, with the other sciences (chemistry, biology, psychology, and the social sciences) stacked on top, each dealing with mereologically more complicated fusions of physical events than its predecessor. This assumption is often complemented with the principle of the *causal closure* of the physical realm. This principle states, in effect, that physical events (even huge conglomerates of physical events possibly constituting such macro-events as earthquakes, mental states, or a crash in the stock market) are causally produced by antecedent physical events alone (though these latter events may in their turn be more illuminatingly describable in the jargon of relevant nonphysical sciences). That is to say, fundamentally there is only one kind of "real" causation, namely, causation at the level of microphysical events. Thus, causation extends upward all the way from the physical domain to the higher-level domains supposedly stacked up on top.

Consequently, according to this view, causation at these higher levels of existence, in particular mental causation, is always in some sense derivative or epiphenomenal. Jaegwon Kim's doctrine of *supervenient causation,* for example, holds that there exists a macro-causal relation between two events just in case there is a micro-causal relation between the two events upon which they supervene. Clearly such a definition of supervenient causation renders all macro-causation epiphenomenal. In particular, since mental causation is a species of macro-causation, the way the mind matters in this world is, on this view, epiphenomenal as well. It has been observed, however, that Kim's doctrine presupposes an unnecessarily restricted notion of event-supervenience known as *local supervenience.*

See also CAUSATION; DOWNWARD CAUSATION; SUPERVENIENCE

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THEO C. MEYERING

V

VALUE

The word *value* commonly refers to the worth of something: an object or event, a person or action, an idea or institution. Its value can be understood as objective, a quality or feature it possesses independently of one's experiencing it. The sunset is beautiful whether it is observed or not; honesty is the best policy even if people do not think so. A thing's value can also be understood as subjective, a positive feeling or idea that it arouses or that is imputed to it. Good art is whatever one happens to like; moral codes are social constructs. In economics, the (subjective) market value of a commodity or service is the price someone is willing to pay for it at a given time; its (objective) normal value is the price it would command in a perfectly functioning open market. By metaphorical extension, the value of a variable in mathematics is its assignable numeric worth: The value of x in $2 \times x = 6$ is 3.

Value is also a verb. To value something is to esteem it, to take it into account in making a choice, to assert its objective or subjective worth. The American philosopher and educator John Dewey distinguishes between prizing and apprizing: To prize something is to like it, to appreciate it, to enjoy the experience of it. There is no explanation required: People simply like what they like. Dewey calls these *de facto* values, which he contrasts with *de jure* values, values that have been judged, with respect to their causes and consequences and by comparison to other alternatives, to be genuinely worthwhile, not only desired but desirable. Just as science has an experimental method for discriminating warranted from unwarranted hypotheses, Dewey argues, so a method of criticism is needed for discriminating among values, helping people select those values most conducive to their self-realization and to the attaining of a common good.

A thing's value can be either intrinsic, itself the source of its value, or extrinsic, the source of its value lying elsewhere: in God's will, a subjective judgment, or another value upon which it is dependent. In a context of means and ends, a thing has *final* value (sometimes, confusingly, called its intrinsic value) if it is the goal of a purposive effort; it has *instrumental* value if valued as a means for achieving that goal. Dewey argued that all values are both final and instrumental: Any end one seeks is also a means toward further ends. In the eighteenth century, the philosopher Immanuel Kant argued that rational beings are ends in themselves: They have infinite worth because there is no other value for which their value could legitimately be sacrificed, made merely a means. Note that all instrumental values are extrinsic, but some extrinsic values are not instrumental: Theistic religions claim that persons are valuable not intrinsically but because they are created by God.

Value theory, or *axiology,* an approach in which value as a general category is made the primary object of philosophical analysis, is a nineteenth and twentieth century development in Western thought. Among the leading value theorists are Bernard Bosanquet, J. N. Findlay, Alexius Meinong, and Max Scheler in Europe; Alejandro Korn in Latin

America; and C. I. Lewis, Ralph Barton Perry, John Dewey, and Stephen Pepper in the United States. Their strategy is usually to provide a generic analysis of the nature and conditions of value, then to apply these concepts to the various realms of value their theory either predicts or interprets.

Traditionally, however, thinkers have concerned themselves not with value in general but with specific values: aesthetic (beauty), ethical or religious (goodness), and scientific or philosophical (truth). Sometimes these kinds of value are thought to be distinct, for instance, claiming that the criteria for a thing's being true have nothing to do with its desirability. Others argue for a hierarchy among the kinds, usually in terms of some version of Plato's divided line, beginning with the transient values of immediate perception and imagination, rising through practical and then theoretical concerns, and arriving finally at something ultimate, the source of all lesser values: a contemplation of the Form of the Good or of Beauty, or communion with God or the Absolute. In the early nineteenth century, the philosopher Georg Wilhelm Friedrich Hegel temporalized this hierarchy, so that the ultimate became not an eternal governing ideal but a historical culmination, not a governing rule but an achievable goal.

The notion of a "final value" for individuals to achieve is usually given an ethical slant. Aristotle, for instance, finds this achievement to be the happiness that comes from a life of appropriate actions accomplished with excellence. Confucius recommends combining principled action with energetic striving, melding Heaven and Earth into a moderate way of living. For the Stoic, one's culminating humanity is to be found in tranquility of mind; for the Christian, in selfless love; for Friedrich Nietzsche, in the effective exercise of one's will to power; for Josiah Royce, in loyalty to a cause; for Jean-Paul Sartre, in authenticity.

This notion of a value as an achievement, as a quality of something made, has been explored metaphysically by pragmatists and process philosophers. For instance, Robert Cummings Neville, influenced by Charles Sanders Pierce and Alfred North Whitehead, argues that all values are achievements of harmony. A value is an integration of diverse elements. The more they are diverse, the more complex the attained harmony; the more complete or intense their integration, the more simple the harmony. Complexity and simplicity are opposites, however. The challenge is to increase both in a harmonic contrast, making the most value possible in a given circumstance. Neville then works out the implications of this theory for the traditional realms of value, defining truth, beauty, and goodness as kinds of harmonic contrast.

One's personal values are evidenced by the things one finds valuable. Insofar as they are compatible and consistently held, they comprise one's personal value system. Emile Durkheim argues that for people to be organized into communities it is necessary that individual value systems be subordinated to a shared social value system. God, says Durkheim, is that historically fashioned cultural value system projected as an ultimate reality independent of those who hold it. Hence should the societal order break down, its members will feel alienated from God, stripped of their sense of worth: They will suffer a condition of valuelessness, the despair of anomie.

See also AESTHETICS; AXIOLOGY; BEAUTY; VALUE; VALUE THEORY; VALUE, RELIGIOUS; VALUE, SCIENTIFIC

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Roger L. Funk. Evanston, Ill.: Northwestern University Press, 1973.

GEORGE ALLAN

VALUE, RELIGIOUS

Value functions in religion in at least three ways: as the ground of obligation, as the framing values orienting culture and thinking, and as specific moral traditions.

Value as the ground of obligation

One of the chief functions of religion is to explain why people should be moral or spiritual at all, and to cultivate a fundamental human constitution of living under obligation. Religions define people as responsible. Even in vaguely antireligious secular societies such as those of the North Atlantic nations at the beginning of the twenty-first century, this obligation-making function is recognized as "civil religion." When religions fail to function even as civil religions, serious relativism gains currency, as has been analyzed by Robert Bellah (b. 1927) and his collaborators.

Religions represent fundamental human obligatoriness to rest on what they take to be ultimate, as examined by the Comparative Religious Ideas Project in *The Human Condition* and *Ultimate Realities,* as well as by Ninian Smart (1927–2001). Roughly speaking, the religions of East Asia, Confucianism and Daoism, take the ultimate or Dao to be intrinsically good with powers by which human beings can become great. Obligation in the East Asian context has connotations of attunement and participation in cosmic and social orders, and as such is friendly to science in the form of practical technology, ranging from ancient practices of medicine and dietary regulation to modern scientific technology. The main religions of South Asia, including the many forms of Hinduism and Buddhism, consider the ultimate to involve some version of a contrast between what is apparently real in daily life and what is really real. The notion of living under obligation in these religions has connotations of coming to enlightenment about this distinction, observing culture-building obligations regarding daily life on the one hand and religious fulfillment or actualization obligations regarding what is really real on the other. Because science is regarded as studying the daily world of appearances, South Asian religions can encourage both theoretical and practical science with great enthusiasm: Science is detached from concerns for what is really real, and can stand in little conflict with theological interests.

The West Asian monotheistic religions of Judaism, Christianity, and Islam symbolize the ultimate as a God who creates the world and to whom people are responsible in freedom. In the ancient metaphors, God is like a king who issues decrees that obligate people; to be a person is to stand before God as before a judge. Science often is prized in West Asian religions as a way of understanding God, creation, and the divine norms. This was particularly so in medieval Islam and in European science in the modern world. Nevertheless, the imperatives associated with the moral traditions of these religions can be in conflict with those that seem to arise from scientific understanding. West Asian religions engender conflicts between "conservative" religious values and "modern" scientific ones, conflicts that are more difficult to engender in some other Asian religious traditions.

The common distinction in modern European science between facts and values is of utmost importance regarding the religious function of defining obligation. Early modern science modeled itself on mathematical systems and sought to characterize the world as a set of explainable facts and value-neutral laws. By implication, value was supposed to be derived from human interest or projection, not from the nature of things. Although there have been attempts to define human obligation within a scientific system, as for instance in the modern social contract theories of Thomas Hobbes (1588–1679) or John Locke (1632–1704), the cultural upshot of the modern scientific distinction between fact and value is to say that the ground of obligation cannot be known and is a matter of personal or subjective preference. Hence the existential cultural importance of the question, Why be moral? If a person can choose not to be moral, there seems to be nothing in the nature of things to indicate that this would be a mistake. So long as modern science has a "factual, non-value" philosophy of nature, it tends to undermine the religious grounding of obligation, regardless of which religious conception of ultimacy is operative.

Value as cultural orientation

The function of religions to provide framing or orienting values for cultures has already been mentioned. The East Asian orientation to the ultimate as attunement and participation is associated with positive assessments of the value of life, nature, and human social affiliations. Disease, moral failings, and spiritual perversity are interpreted as misattunements, not invincible ignorance or sin. Whereas Confucianism emphasizes positive cultural work to attain attunement, Daoism emphasizes coordination with nature. The South Asian emphasis on a contrast between the world of appearances and the really real produces a divided and balanced kind of orientation: attention to the everyday and a search for release from ignorance (at least on the part of those ready for it). The common belief in the West that South Asian religions do not have strong ethical or scientific traditions is false; those religions just do not associate ethics or science with the religious quest except as preliminaries or supports. The West Asian religions, by contrast, strongly prize freedom and responsibility, and take the issues of justice and righteousness to have an ultimate, divine dimension; human moral failure is a religious offence against God. These religions orient people to the world as a positive expression of divine creation, but also sometimes treat nature as providing temptations to sin because people have a direct relation to God (namely, obligation) setting them apart from nature.

The great religious traditions have evolved through centuries, and the shape of their framing value orientations has shifted accordingly. The East Asian religions were deeply impacted for centuries by Buddhism from India. The South Asian religions have interacted with Islam and Christianity. The West Asian religions have exhibited both world-denying forms (as in early Christian asceticism) and world-celebrating forms. The contemporary interactions of the great world religious traditions reflect both their long histories and the fact that each has become a global religion, with cultural embodiments in each of the world's cultures.

Precisely because religions are culturally embodied, the values otherwise resident in their various cultures are powerful within the thinking of the religions themselves. National interests, for instance, can define different expressions of a religion against one another. The wars between Iran and Iraq in the twentieth century, or between the Christian nations of Europe, have involved calling upon the same religious tradition to justify each side against the other, reinforcing different interpretations of what the religion means.

As orientations to science, the framing values of the different religions have the effects already suggested. East Asian religions value science for its practical benefits. South Asian religions promote an objective detachment about science because it is not concerned with ultimate matters in the form of the really real or ultimate religious quests. West Asian religions can promote science as a kind of piety inquiring into the mind and work of God, on the one hand, and fear it as the source of norms different from those of the tradition, especially the norm of objectivity that treats the world as a mere fact without value.

Value as traditions of morality

The great religions have long traditions of moral interpretation reflecting their historical and cultural locations and changes. Within each tradition are often to be found arguments representing many sides of basic issues treating war and peace, patterns of family and social life, proper respect for people in conditions of birth and death, life transitions, and suffering. For instance, most religions have both pacifist and just-war moral traditions.

The development of modern science has affected religious moral traditions in many ways, two of which are the following. Most moral problems are framed by conceptions of natural conditions. For instance, the ancient Greek belief that the homunculus or complete human being is contained in the male sperm made it plausible to condemn as murder any male sexual activity, including masturbation, not reasonably intended for impregnation. This argument, though perhaps not the sentiment, falls away completely when it is realized that a human being requires genes from the mother's egg as well as from the father's sperm. Or to mention an example from the social sciences, distributive justice could not be taken to have a global scope so long as international economics was not understood in systematic ways. For example, during the

Middle Ages, the Christian thinker Thomas Aquinas (c. 1225–1274) could consider distributive justice as limited to a king's domain. But with the advent of empirical global economic theory, the problem of developing theories of global distributive justice is suddenly a forced option for religious moral thinkers.

In addition to the impact of science on moral theory, the development of scientific technologies has led to moral problems that did not exist before. The invention of large bombs makes the old just-war theories, which are based on restraint, obsolete. Biological technologies of cloning, organ transplantation, and genetic manipulation lead to dilemmas that were not previously imagined. Insofar as moral responses to new problems raised by technological advances are to come from developments of the religious moral traditions, the religious values themselves are in process of evolution.

See also NATURAL LAW THEORY

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ROBERT CUMMINGS NEVILLE

VALUE, SCIENTIFIC

Few terms are as subject to confusion as the word *value.* Used as a noun, it denotes objective things, states, processes, or qualities that are approved, desired, or found worthy by at least one valuer (e.g., "At first, money was Scrooge's only value."). Used as a transitive verb, however, it denotes the subjective condition of appreciating, approving, or desiring something (e.g., "I value your smile."). It may refer to what is positively appreciated by a single subject, but also to what is found worthy by groups, who may share purposes, preferences, and norms (e.g., "Middle class values are in flux."). Since different individuals or groups may approve different things, values between valuers may clash, and debates may rage over whether someone else's value is really a value at all. Further, since many different, and sometimes incompatible, types of things may be found worthy even within the same group or by the same individual, there may be internal clashes. Wealth, practical skills, social graces, moral virtue, artistic beauty, intellectual insight, spiritual fulfillment—all may be found worthy in principle, but perhaps not equally worthy in all circumstances. When values conflict, were some not really values after all? The response of this entry will be pluralistic, recognizing many different species of value as entirely genuine, firmly grounded in human goals and purposes, and therefore inescapably interconnected, though often in tension.

The purposes of science, a human activity involving economic consequences, technical skills, social mores, ethical concerns, aesthetic judgments, intellectual thirsts, metaphysical preferences, and religious implications weave themselves into a skein of reinforcements and conflicts within at least three distinguishable domains: the needs of scientific practices, the goals of scientific theorizing, and the norms of culture generally.

Values and scientific practices

Sometimes overlooked are the values that initially draw people into engaging in scientific practices. Today going into science is a way of earning a living. This has not always been so. Before the professionalization of the modern sciences, scientific work required private means or wealthy sponsors. Private economic values, though real, can hardly be basic. Sheer delight in acquiring and using skills for manipulating the natural order would doubtless be more fundamental historically and psychologically. Even deeper would be a lively curiosity about the way things work that leads some people to probe and tinker. And behind the enterprise as a whole loom human needs that might be met if only answers could be found and events controlled. Social goals, such as fame and prestige, or the hope to be first at solving a problem or developing a technique, also figure into the rich mixture of motivating values.

Techniques carry with them their own set of values. A *technique* is a generalized way of doing something. It presents a norm for approximation. A *skill* is the disciplined capacity to carry out a technique, requiring attentiveness and muscular control coordinated to deal with particular circumstances. At a minimum, scientific practices inherently call for the technical values of accuracy and precision, and of approximating, as well as possible, the norm represented by the technique. They demand that the practitioner acquire and maintain personal skills capable of providing regular, repeatable outcomes. Replicability, therefore, emerges from practice as a primary scientific value. And with replication comes counting. Quantifiability, to whatever extent circumstances allow, is a value rooted in the practice even of a lone scientific investigator.

The social character of modern scientific practice underscores and amplifies the importance of these values of accuracy, replicability, and quantification. Others who have acquired the necessary skills must to be able to achieve similar results. They must come up with similar numbers. Further, the practice of scientific publication reinforces the built-in need for such values as precise experimentation and record-keeping, accurate reporting, accountability to colleagues, readiness to submit to community standards, and (in principle at least) even the willingness to welcome the possibility of falsification in the larger interests of scientific reliability.

Where truth-telling, cooperation, and community responsibility are involved, technical values implicit in scientific practices lead inexorably to ethical ones. But not all ethical values relevant to scientific practices are internal to the requirements of technique alone. Scientific values do not generate compassion. Independently acquired moral standards of scientists are needed to forbid some kinds of practices—where humans might be subjected to torture or vivisection, for example—despite the possibility of making interesting discoveries. Such external restraints involve still larger normative conceptions. What is it to be a human person? What sorts of practices are compatible with a person's moral status? Different ages and cultures give different answers, which may ultimately root in religious commitments or metaphysical convictions. The science of anatomy was dependent at one time on systematic grave robbery, since autopsy was forbidden on theological grounds. The practice of vivisection on dogs and cats was supported by the followers of René Descartes (1596–1650), who held that animals, lacking speech and rationality, had no souls and therefore were incapable of feeling pain.

Values and scientific theories

Values motivating the construction of scientific theories certainly include the same curiosity noted in connection with scientific practices, but now the quest is not simply for how things work, but why. What is going on behind the scenes? What makes things happen as they do? Part of what is valued here is enhanced ability to control outcomes by grasping hidden processes. But for many there is also a deep thirst for understanding simply for its own sake.

If understanding offers intrinsic as well as instrumental value, there are other important values prerequisite to achieving this end. These are the intellectual values that make intelligible theory possible, beginning with logical consistency (since inconsistency cancels meaning and makes any account of things impossible), including systematic coherence (since the elements of an account need to hang together if they are to tell a unified story), and—in the case of all empirical sciences—resting on evidential adequacy and comprehensiveness (since if a theory is to be about something, it must take account of as much data about that something as possible). There are potential conflicts among these values, since coherence is more easily achieved if evidence can be limited to exclude inconvenient facts; contrarily, adequacy can have freer run if it ignores norms of consistency and coherence. Still, the job of theorizing must operate within these tensions.

Working within such human limitations, additional values are often important to the construction and later acceptability of theories. Theorists may be inspired in their constructive quests by the aesthetic values, for example, of simplicity and symmetry. Community acceptance may be influenced, as well, since an elegant theory is more to be admired, and may be easier for minds to grasp, than a ramshackle construction. However, since there are many different ways of approaching simplicity and other aesthetic values, as well as multiple interpretations of coherence, and arguably clashing estimates of relevance, it is clear that human judgments of better or worse continue to be indispensable and pervasive in the theoretical sciences.

Undergirding all such judgments are fundamental ethical and religious values. Moral integrity is required in acknowledging available evidence, perhaps despite personal preferences, and following the logic of argument where it leads. Further, acceptance of the value of knowledge as a fundamental good, commitment to the norms of honesty, and reverence for the pursuit of truth, even in limited domains, may lead to (or flow from) unlimited, or ultimate, expressions of value so intense and comprehensive as to be functionally religious.

Values and scientific culture

Cultures shaped by scientific practices and theories reap huge economic values, as technologies developed by unprecedented understanding of how things work provide unprecedented means of control and exploitation of the Earth's wealth. Unfortunately, equally huge economic and environmental disvalues, too, haunt scientific cultures whose grasp of physics and chemistry outstrips understanding in ecology, sociology, and the humanities.

Intellectually, scientific theories offer scientific cultures unprecedentedly adequate and coherent accounts of how things are, as well as how they work. In particular, the grand narrative woven from scientific cosmology, physics, astronomy, geology, evolutionary biology, paleontology, and archaeology provides a new framework for interpreting the universe. Since the powerful hunger for such frameworks has long been fed by older, nonscientific narratives, there is inevitable conflict with comprehensive prescientific alternatives in which maximally intense values have long been invested. Efforts to oppose or nullify evolutionary theory, for example, can be seen as counter-attacks against scientific thinking by disaffected members of scientific culture whose primary religious values are threatened.

The primary scientific values, in contrast, are found in loyalty to a public method—in experimental practices as in theorizing—in which all evidence is honored in principle and conclusions are proportioned to fact and norms of logic. Such values advocate a rational culture, in which all disputes are resolved by dialogue. As noted above, however, unsupplemented scientific values emphasize quantitative over qualitative considerations and are notably lacking in compassion. In the much needed dialogue between science and its culture, scientists are not the only ones who deserve a hearing.

See also VALUE, VALUE THEORY

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FREDERICK FERRÉ

VALUES, ORIGINS OF

See RELIGION AND VALUES, ORIGINS OF

VALUE, VALUE THEORY

A value theory indicates the characteristics common to values of all kinds, classifies them, and clarifies the meaning of value-propositions. The kinds or "realms" of value are always said to include moral and aesthetic values, but other kinds are usually mentioned also. For instance, Paul Taylor (1925–) lists six others: intellectual, religious, economic, political, legal, and customary realms of value. All value theorists claim that even though there are striking or important differences among kinds of value, their similarities are more fundamental. As Ralph Barton Perry (1876–1957) puts it, value theory pulls concerns "dispersed among the several philosophical and social sciences" into a single "comprehensive inquiry" in which these various pursuits are "unified and distinguished," so as "to bring to light the underlying principles common to these sciences, and then to employ this principle for the purpose of arbitrating between them" (p. 9).

Value theory is a nineteenth-century development in Western philosophy. Its initiator is usually said to be the German philosopher Rudolf Hermann Lotze (1817–1881) who sharply distinguished *fact* and *value,* arguing that fact was the province of the natural sciences, whereas the humanities concerned themselves with value. Value theorists after Lotze can be grouped into two strands: those who claim that values are discovered or created solely by minds, and those who claim that values are empirical features of things or actions. Contemporary analytic philosophers belong to both strands, differing from their predecessors by limiting their investigations to the language used in asserting or recommending a value. Some metaphysicians reject this limitation and offer grounds for thinking that values are ontologically fundamental.

Strand one: conceptual

Franz Brentano (1838–1917) argues that values are rooted in human emotions, in the contrast between favorable (love) and unfavorable (hate) intentional attitudes toward objects and events. His student Alexius Meinong (1853–1920) elaborates this notion by identifying four aspects of any value experience: a *value subject* who experiences, a *value feeling* or emotion, a *value object* toward which this feeling is directed, and an *existence judgment* that ascribes the feeling's cause to the object. For example, a person watching a sunset has a positive emotional feeling, which the person claims is because of the sunset. Meinong argues that a value emotion is neither independent of publicly verifiable (scientific) fact, as Lotze claims, nor reducible to fact: It is a subjective feeling that can be judged to be reasonable or not by reference to the relevant facts.

J. N. Findlay (1903–1987) offers a mid-twentieth century version of the Brentano-Meinong view. Consciousness, he argues, has an "intentional" structure: It is always of an object. Belief is unconditional assent to the reality of the object of an intention; action is an endeavor to bring an intended object into existence. For an action to be sustained over the time needed to achieve this goal, the feelings of assent and endeavor that accompany it need to persist. A person's values are those feelings that function as "the relatively fixed points of the compass" by means of which one's "choices are guided" (p. 204). The "firmament" of the values by which a person is guided is "rationalized" by abstracting from the particularities of the several values and framing general integrative guiding principles that are detached from the urgency of particular pragmatic interests. The apotheosis of this generalization process is the formulation of "absolute values," norms governing both individual and collective endeavors.

Religious values, Findlay argues, are absolute values extended beyond those associated with human beliefs and efforts, having to do with intentional structures that are holy—in the sense of strange and numinous—because radically inclusive. They are radically impersonal, however, expressing "the pattern of a detached, suprapersonal, norm-setting *mind*" (p. 399). The genius of Judaism, Christianity, and Islam is that they recognize the need people have for this impersonal absolute to be embodied in a supreme religious object that has some direct connection with common everyday realities; the absolute value must be incarnate in history, in specific acts or persons.

Strand two: empirical

Feelings or intentions are unobservable mental states. Those who want value theory to be a scientific enterprise therefore turn from feelings to "interests," from intentions to "behaviors," from introspection to "motor-affective responses." C. I. Lewis (1883–1964), for instance, insists that evaluations are a form of empirical knowledge. Their truth or falsity, is determined in exactly the same way as the truth or falsity of nay other kind of empirical knowledge is justified. Directly experienced satisfactions have "intrinsic" value, but no object can have intrinsic value because its value consists not in what it is in itself but rather in the possibility of its leading to some realization of directly experienced value. The object need not in fact lead to such experiences, but only have the potentiality for doing so: A Paleozoic sunset had objective value even if no human being was actually there to enjoy it. Where an intrinsic value experience is afforded by the presentation of an object, that object has inherent extrinsic value. Where one object is a means by which to come into the presence of another object that has inherent value, the first object has "instrumental" and possibly "contributory" extrinsic value.

Ralph Barton Perry makes this notion of intrinsic value central. Any object acquires value by becoming the target of some interest: "that which is an object of an interest is *eo ipso* invested with value" (p. 115)—"x is valuable = interest is taken in x" (p. 116). Perry distinguishes between a "value preference" (a subject has more interest in *x* than in *y*) from a "judgment of comparative value" (a subject asserts that *x* is better than *y*). The latter involves standards of measurement and so, unlike a value preference, is open to correction. Love is a favorable interest in the satisfaction of a second interest, that of another person. So the highest possible value is that of an all-loving will. Such love could not be the interest of a single person, however. Perry's alternative to Lewis's religious absolute is a "federation," a multiplicity of independent equally valued persons, united by their devotion to the same value ideal, expressed through reciprocal acts of love.

John Dewey (1859–1952) rejects the distinction between value judgments and factual judgments. Valuation takes place whenever a problematic situation exists, whenever an expected enjoyment is blocked. Some inquiry needs to be undertaken in order to resolve the problem, to reshape things in the light of an ideal about how things might be such that the desired enjoyment might be experienced. A value is not an enjoyment but an interest in attaining one, and hence involves a proposal for how to do so. Values can therefore be appraised—critiqued, ranked, and revised—with respect both to how effective they are as guides for attaining the enjoyment sought and to how satisfying that result is. Values are an important aspect of the natural sciences, since hypothesis formation in scientific inquiry is an instance of valuation and its critique. Dewey argues that progress in the improvement of the human condition is impeded by the traditional insistence that actions guided by aesthetic, moral, political, and religious values are timeless absolutes grasped emotionally, matters of tradition or feeling or faith—values isolated from scientific values, and hence from "intelligent" meliorative rational control.

The language of valuation

Twentieth-century Western philosophy has been dominated by linguistic concerns, and so value theory for many thinkers has been limited to a consideration of value-propositions: What the nature of assertions of value is and whether or how values are justified. These approaches can be grouped into the same two strands as earlier value theories: those primarily conceptual and those primarily empirical.

One kind of mind-centered approach claims that value-propositions make no reference to facts and so are neither true nor false. Charles Stevenson (1908–1979) calls such propositions "emotive." A person who asserts that "this is a beautiful sculpture" says nothing about the sculpture. He only expresses his positive feelings toward it: "this sculpture, wow!"

A quite different approach, with G. H. von Wright (1916–) as a key figure, is to explicate a "logic of preference," to assess value-assertions in terms of a logical system governed by syntactic and semantic rules. For instance, "possible worlds" might be ranked by means of an "index of merit." Next a proposition could be assigned a "generic value," understood as the average of the merit rankings of the worlds in which its value is meaningful. Then proposition x would be "rationally preferable" to proposition y if its generic value is higher than y's. Game theory and decision theory are two related developments of this logico-mathematical approach to valuation.

Those analysts of the language of values who stand in an empiricist tradition draw from informal rather than formal logic, with the later writings of Ludwig Wittgenstein (1889–1951) often key. Paul Taylor's work is illustrative. He distinguishes normative discourse from scientific discourse, arguing that they are governed by differing "canons of reasoning." Taylor is particularly concerned with the way in which value judgments, the "first-order" content of normative discourse, can be justified. To "verify" a value judgment is to appeal to established standards or rules of evaluation. If these are questioned, one must "validate" them by appealing to higher-order standards or rules, and ultimately by appealing to those principles that determine a "value system." To take a "point of view" is to commit oneself to following a certain set of rules of relevance in deciding which value system to accept as governing one's value judgments. There are as many points of view as there are kinds of value systems: for instance, a moral point of view and an aesthetic point of view. A "way of life" is the set of value systems expressing all one's points of view, arranged in some integrative hierarchical manner. If a person's value system is questioned, it is "vindicated" by appeal to one's way of life. When a way of life is questioned, the only justifying appeal is to "rational choice": showing that one's value commitment has been arrived at by a deliberative process that is free, enlightened, and impartial.

Metaphysical value theories

Dewey argues that value theory is a response to the expulsion of teleology from nature: the claim of modern science that facts are adequately explicated in terms of efficient causes, without recourse to final causes or purposes. Value theories of almost any sort can be challenged by attacking the metaphysical presuppositions of modern science, arguing that the natural order is in some sense purposive, that ends and ideals are features of all natural processes, and that to exist is to have and to be making value.

A contemporary example of such a value-based metaphysics is found is the work of Frederick Ferré (1933–). He argues that "the process of an entity's coming to be something definite" involves "the generation of intrinsic value for the entity concerned" (1996, p. 357). The basic factual entities of the universe are self-fashioning processes involving the integration of diverse elements into a definite unity, a harmony. To achieve any sort of harmony is to generate beauty, so for Ferré a cosmos composed of beauty-fashioning entities is "inherently kalogenic." Given such a universe, an ethic obviously follows in which not only persons but other organisms, indeed entities of every sort, should be treasured for the value achieved in their existing and for their relevance to possibilities for future value realization.

William Desmond (1951–) takes a different approach, recognizing the diversity of value-creators but insisting that their power to create value and their aspiration to do so depends on recognizing the origin of what-is in a transcendent power. Humans live in the *metaxu,* between Being and nothing at all—astonished that they exist, affirming that it is good they and others exist, dwelling together. Insofar as humans are "mindful" of these wondrous facts, they will be aware that there is an origin of their existing, that their lives are a gift, a good that need not have been but nonetheless has been freely given them. Desmond calls this overflowing good of the originative power "agapeic"—a good given for the other's good, a freedom that frees others rather than subordinating them, a power that empowers others to express their powers in a giving such that the good of others and the common good are enhanced. Desmond therefore argues that the ideal of human moral development is "agapeic service"—practicing a self-surpassing ethics of generosity in response to God's freely given infinitely valuable gift of life.

See also AESTHETICS; BEAUTY; VALUE; VALUE, RELIGIOUS; VALUE, SCIENTIFIC

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GEORGE ALLAN

VIRTUAL REALITY

Virtual reality is that part of human experience that does not happen in a physical space. Reading a book creates virtual reality, as does participating in an online chat or a telephone conference. These experiences are called "virtual" because the people involved are not actually in the story of the book or in a conference room with other people but physically separated; nonetheless, they participate in the community through thought and imagination and, in some cases, through their eyes, via the monitors, and fingers, via the keyboards.

The term *virtual reality* came into wide use during the 1990s with the increasing popularity of the Internet, and the concept of virtual reality led to many of the metaphors used to describe Internet interactions. A chat room, for example, is not a room, and it does not even have a physical location; it consists entirely of the people who are "meeting" there and interact. They do not meet, of course, but happen to be at their personal computers at the same moment in time. They also do not chat or talk but write messages that appear on others peoples' screens. Keyed graphics called *smileys,* such as :-) and ;-}, convey emotional content. Sometimes people wander off into separate "rooms" to be more "intimate" with a few others instead of sharing their thoughts in "public." These and many other metaphors are used for two reasons. First, humans are physical entities, and, from an evolutionary perspective, everything they did in the past happened in physical time and space. Language arising from this background is naturally physical in its description of human interaction. But once these metaphors are used they also become a selling point for virtual reality because they suggest that virtual reality allows for complete personal interactions.

Despite their obvious popularity, chat rooms and other virtual reality entities raise serious questions. One of the most obvious is the fact that among virtual reality communities there are several churches and prayer groups. The question is, can such spiritual virtual reality communities actually replace mortar and brick churches? Cybercommunities lack the physical space that bodies, together in liturgy and practice, create. Gender, race, and age have no defined roles. In virtual reality, people can lie about themselves and construct different identities. In addition, virtual reality communities give people the freedom to project all their wishes and desires about a "real" community onto the cyber-community because there is no way to know who is there and if the people are actually likeable. But is this community? And where does this wish for clean and perfect relationships come from when everyone knows that real-world relationships are flawed, stressful, full of ambiguities, yet so much fun. Because there is no physical commitment or connection in cyberspace, web communities may be ultimately indifferent and meaningless to the people involved.

The understanding of humankind in recent years has changed from a dualistic, cognition-oriented understanding toward an embodied and social one. The intelligence of humans is not the main characteristic of the species—it is much more the human capacity to connect and to survive in any given environment. Virtual reality, however, is a direct result of the assumption that embodiment and shared physical space are not important for community building because the body is not part of what turns a human into an individual. But if cognitive science theories are correct, then virtual reality spaces lack the required physicality, and relationships in them are incomplete.

See also INFORMATION TECHNOLOGY

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ANNE FOERST

W

WAVE-PARTICLE DUALITY

The quantum description of matter ascribes a wavelike aspect to particles of matter. In some circumstances, for example in the photoelectric effect, particles behave primarily as if they are mass points. In other circumstances, they display diffraction and interference as if they are waves. The quantum wavelength of a particle is inversely proportional to its mass, and an object's wavelike aspects will be significant whenever its quantum wavelength is larger than its physical size. Therefore, large objects like cars have imperceptible wavelike attributes but subatomic particles, such as neutrons, have significant wavelike aspects. It is more accurate to view the quantum wave aspect as being a wave of information (like a crime wave) or probability than an undulatory quality.

See also PARADOX; PHYSICS QUANTUM

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JOHN D. BARROW

WHITEHEAD, ALFRED NORTH

Alfred North Whitehead (1861–1947) believed that the future course of world history depends upon people's decisions as to the relation between science and religion. In fact, the force of religious intuitions and the force of scientific endeavors are the two most powerful forces in history. Whitehead's solution to conflicts between science and religion was to suggest modifications in both science and religion, as each has been traditionally understood, so that an inclusive alternative worldview might be constructed. He turned to speculative philosophy for this constructive task. Whitehead proposed that philosophy attains its chief importance by fusing religion and science into one rational scheme of thought.

Life and influences

Whitehead was born in Ramsgate, England and grew up the son of an Anglican clergyman. His keen intelligence was evident early in life, and, when offered college scholarships to pursue either mathematics or classic literature, he chose the former despite what would be a lifelong fondness for the latter. After a stint as student at Trinity College of Cambridge, England, Whitehead continued on at the school for twenty-five years as fellow and professor. He also took up rigorous theological studies for nearly a decade. As a result of his study, however, he decided to affirm atheism. Whitehead was also elected a fellow of the Royal Society due to his prowess in universal algebra. During this time, he coauthored with fellow philosopher and mathematician Bertrand Russell (1872–1970) one of the most important philosophy books in twentieth century, *Principia Mathematica* (1910–1913).

Following his stint at Trinity, Whitehead moved to London and held positions teaching mathematics at University College London and London's Imperial College of Science and Technology. He served in a number of administrative capacities, including Dean of the Faculty of Science. Whitehead's interest in science resulted in the publication of *Principles of Natural Knowledge* (1919), *The Concept of Nature* (1920), and *The Principle of Relativity* (1922). The insights gained from academic supervision comprise the heart of his influential work pertaining to educational philosophy: *The Organisation of Thoughts* (1917) and *The Aims of Education* (1929).

In 1924, at age sixty-three, Whitehead left London for the United States to teach philosophy at Harvard University in Massachusetts. Whitehead was his most productive as a writer during his Harvard years, and the work he produced provides the basis for how he believed science, religion, and philosophy ought to relate. He wrote his most influential books while at Harvard, including *Science and the Modern World* (1925), *Religion in the Making* (1926), *Adventures of Ideas* (1933), and his magnum opus *Process and Reality* (1929).

Philosophy

Whitehead may have best summarized his overall view of the relationship between science and religion when he wrote, "you cannot shelter theology from science, or science from theology; nor can you shelter either one from metaphysics, or metaphysics from either one of them. There is no shortcut to the truth" (1926, p. 79). The convictions expressed in this statement prompted Whitehead to frame a coherent and logical system of general ideas in terms of which every item of experience could be interpreted. He was insistent that an adequate metaphysics or worldview must account for whatever is found in actual practice, including scientific and religious practice.

Although Whitehead had chosen atheism earlier in life, his stance toward God and religion changed as he attempted to construct an adequate worldview to account for science and religion. Like Aristotle twenty-three hundred years earlier, Whitehead came to postulate the existence of God because he found that the general character of reality requires an all-embracing, purposive, and loving deity.

Whitehead departed from Aristotle, however, in his primary insight that actual existence involves a process of becoming, rather than fixed states of being. Evidently influenced by quantum physics and Buddhism, Whitehead considered these basic units of actual existence to be events or moments of experience rather than bits of unalterable matter. Although the specific makeup of these events differs radically, every event exemplifies the same metaphysical principles.

The process of existence, argues Whitehead, is twofold: It is the becoming of events and the transition from event to event. Each event, occasion of experience, or *actual entity* (he uses these terms interchangeably) exists first as a subject and then as an object. Present events (subjects) are influenced by prior events (objects), and these events, when completed, become objects that exert influence upon subsequent subjects. An *enduring individual* in this process of becoming is a personally ordered chain of events, rather than a single, self-contained mind.

The process of life in which all things flow is a person's first vague intuition. And "the elucidation of meaning involved in the phrase 'all things flow,'" Whitehead argues in light of this intuition, "is one chief task of metaphysics" (1978 [1929], p. 208). Because he considers the flow of events to be primary, Whitehead's thought is often identified as *process philosophy.* This insight corresponds well with the general theory of evolution.

To say, however, that "all things flow" does not mean that all features of reality are changing. The principles of the universe, for instance, are eternally binding and, therefore, never change. Some aspects of God are also unchanging. These principles and aspects, however, are not actual events.

Not only are events the fundamental units of life, each essentially relates to others. When explaining how moments relate, Whitehead spoke of internal and external relatedness. Internal relations develop as each event arises out of its inclusion of prior events. The event begins with a "open window" to the totality of the past. Once the influence from the past has entered, the window closes and the entity forms itself in response to past influences. Whitehead calls this drawing upon the past via relations a *prehension,* and in this activity the production of novel togetherness occurs. The relations that an event has with past events are its internal relations; the relations it will have with events to come are its external relations. In short, interdependence is primary, because all events relate in community.

Whitehead's organismic philosophy of life, which supposes that all events are experiential and relational, presupposes that all events perceive. Perception is not limited to receiving sensory data by means of sensory organs (i.e., eyes, ears, nose). The perception that occurs most frequently is nonsensory, because most events in the universe are not sensory organs. This emphasis upon nonsensory perception, thought Whitehead, serves as a primary basis for overcoming mechanistic and materialistic tendencies in modern science.

The relatedness of all things does not mean that all events are entirely determined by others. Whitehead speculates that all events possess a degree of freedom such that none can be entirely controlled by others. The fact that each moment of experience is essentially free entails that neither the atoms below nor the gods above entirely determine the state of any particular event.

By affirming the necessary freedom of every individual, Whitehead's thought provides a basis for solving the age-old problem of evil. Free creatures, not God, are responsible for the occurrence of genuine evil. God is not culpable for failing to prevent evil because God cannot withdraw, override, or veto the freedom expressed when creatures act in evil ways.

Role of God

Although Whitehead came to speculate that God exists, the vision of God he offers, while congenial with much in sacred scriptures, differs from the visions most philosophers offer. For instance, Whitehead argues that "the divine element in the world is to be conceived as a persuasive agency and not as a coercive agency" (1968 [1933], p. 213). God's inability to coerce, when coercion is defined as *completely* controlling the actions of others, is not a result of divine self-limitation or a moral inability; non-coercion is an eternal law pertaining to all life.

In addition to never controlling individuals entirely, the persuasive God that Whitehead envisions both influences and is influenced by the world. God "adds himself to the actual ground from which every creative act takes its rise," speculates Whitehead, so that "the world lives by its incarnation of God in itself" (1996 [1926], p. 156). Then, "by the reason of the relativity of all things, there is a reaction of the world on God" (1978 [1929], p. 345). Whitehead's explanation of God's role in this reciprocal relation is oft-quoted: "God is the great companion—the fellow-sufferer who understands" (1978 [1929], p. 351).

The essential relatedness of all actualities implies that God has never been wholly isolated. God relates everlastingly, which implies that some realm of finite actualities or another has always existed (1968 [1933], p. 168). Or, as Whitehead argues, God did not dispose "a wholly derivative world" *ex nihilo* (1968 [1933], p. 216). This relational hypothesis provides a framework for affirming consistently that God expresses love in relationship, while also denying that God ever creates through absolute force. Both notions support a process answer to the problem of evil.

Whitehead suggested a novel scheme for how God influences the world. God offers an initial aim comprised of various possibilities for action to each emerging event. This aim is relevant to each event's particular situation. From the various possibilities in this aim, the event freely chooses what it will be. The fact that God provides an aim to all events is one way Whitehead can speak of God as creator. He did not believe that God wholly decides each aim's contents, however, each aim also contains influences derived from the activity of past creatures. God's persuasive activity includes what Whitehead calls the "graded relevance" of each aim's possibilities. Among all possibilities in an aim, one may be the ideal; the others are graded as to their relevance to that ideal. This scheme provides a basis for affirming that God creatively acts upon both simple and complex individuals: from atoms, genes, cells, and molecules to mice, whales, apes, and humans.

In offering an initial aim to every event, God acts, according to Whitehead, as the "goad towards novelty" (1978 [1929], p. 88). God offers new possibilities for more intense love and beauty when accounting for the past in light of the future. Because these possibilities are offered, a vision of a better way—religiously, scientifically, and aesthetically—is available. Without divine influence, says Whitehead, "the course of creation would be a dead level of ineffectiveness, with all balance and intensity progressively excluded by the cross currents of incompatibility" (1978 [1929], p. 247). Whitehead's belief that God interacts lovingly with creation also presents a crucial underpinning for an adequate ecological ethic.

See also ARISTOTLE; BUDDHISM; DIVINE ACTION; EVIL AND SUFFERING; EVOLUTION; FREEDOM; FREE PROCESS DEFENSE; METAPHYSICS; PANENTHEISM; PHYSICS, QUANTUM; PROCESS THOUGHT

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THOMAS JAY OORD

WOMANIST THEOLOGY

Alice Walker (b. 1944) coined the term *womanist* in her 1983 book *In Search of Our Mothers' Gardens.* Womanist theology is a form of feminism that focuses on the specific concerns of women of African heritage. It centers around their relationship with God, their commitment to the moral flourishing of their communities, and their past, present, and future struggles for justice. The cultural contexts for womanist reflections are diverse. Although the term originates in the African diaspora, others find the emphasis on communal well-being and empowerment relevant to their own cultural contexts. Although womanism situates itself within a theological context, forays into intersections of science and religion tend to focus on issues of healthcare within African American communities, HIV/AIDS, the effects of biogenetic engineering on the poor, environmental racism, and shifting paradigms of dominance and control emerging from new views of the universe.

See also ECOFEMINISM; FEMINISMS AND SCIENCE; FEMINIST THEOLOGY

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BARBARA A. HOLMES

WORLDVIEW

There is a fundamental ambiguity in the way the concept of worldview is used within the science/religion discussion. On the one hand, scholars talk about the *scientific worldview,* by which they mean the picture of the universe that emerges if one brings together the different theories of physics, astronomy, biology, sociology, and so on into a systematic whole. On the other hand, some scholars make statements about the imbeddedness of science *within* a particular worldview, for example, within feminism, Christianity, Islam, or naturalism.

If the concept is understood in the second way, it follows that science alone can never provide a worldview, even though science can, of course, contribute to the formation or revision of a worldview. The reason why is that this conception presupposes that science lacks certain features that characterize a worldview. It is a matter of dispute what these features are exactly, but two elements that science seems to lack are values and metaphysics. A worldview in this sense is typically taken to explain who human beings really are, what the world is ultimately like, and what people should do to live a satisfying life. It gives direction and meaning to life and thus provides people with values. But science offers facts and not values. Therefore, it does not qualify as a worldview. Moreover, no scientific discipline can show whether the physical universe is all that there is. If scientists make such an assertion they make a metaphysical rather than a scientific statement.

Theism and naturalism, on the other hand, offer an answer to this kind of question. Theism says that reality consists of God and all that God has made. Naturalism holds that reality consists of nothing but matter in motion. Therefore, theism and naturalism, not science, are worldviews. Some advocates of scientism question this view, arguing that the boundaries of science can be expanded in such a way that it can offer both values and metaphysics. However, this view is highly controversial, lacking scientific consensus. It is therefore better to refer to it as a *scientistic* rather than a *scientific* worldview.

A worldview need not be well-developed or explicit; the worldviews of most people remain simply sets of background assumptions of which they are not fully aware. The function of such a worldview is primarily to help people to deal with their existential concerns, that is, their questions about who they are, why they exist, what the meaning of their life is, and what stance they should take toward the experience of death, suffering, guilt, love, forgiveness, and so forth. A worldview is thus the constellation of beliefs and values that (consciously or unconsciously) guide people in their attempt to deal with their existential concerns. A religious worldview affirms that people could only adequately deal with their existential concerns if they let their lives be transformed or enlightened by God or a divine reality, whereas a secular worldview denies this.

See also PARADIGMS; SCIENTISM; VALUE

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XYZ

XENOTRANSPLANTATION

Xenotransplantation is transplanting an organ or tissue from one species to another. A shortage of human body parts available for *allotransplantation* (transplantation to other humans) has increased interest in this alternative. Since the 1960s, attempts at xenotransplantation have been made using chimpanzee kidneys, baboon hearts and livers, and pig hearts and livers. Present efforts focus on pigs rather than primates, as pigs reach maturity and reproduce quicker than primates, and pigs are not an endangered species. While pig heart valves are used successfully to repair human hearts, xenotransplantation remains in limited clinical trials. The genetic modification of animals has the potential for reducing human rejection and the danger of transmitting dangerous pathogenic agents. Some researchers have suggested that the transplantation of pig organs to humans may be possible within five years.

How religions evaluate the morality of xenotransplantation hinges on views of animals in the created order. For example, Christianity, particularly Roman Catholicism, believes that xenotransplantation can be justified in certain circumstances since humans have a higher dignity than the animals that serve them. Moral limits, however, preclude transplantation of the encephalon and gonads that are linked indissolubly by their function with the personal identity of humans.

See also ANIMAL RIGHTS; BIOTECHNOLOGY; CHRISTIANITY, ROMAN CATHOLIC, ISSUES IN SCIENCE AND RELIGION; CLONING

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ZOOLOGY

See LIFE SCIENCES

ANNOTATED BIBLIOGRAPHY

About the Annotated Bibliography

This Annotated Bibliography is intended as a starting point for readers who want to explore some of the themes described in the entries in more detail, or who would like to know more about the religion and science dialogue in general. Without claiming to be exhaustive, the Bibliography contains works that are generally regarded as having had a significant impact on the dialogue. The first three sections contain general introductory, methodological, and historical works. Sections four through twelve contain works on specific scientific and/or religious issues. Most works contain extensive bibliographies which will aid further research.

1. GENERAL INTRODUCTIONS AND TEXTBOOKS

Barbour, Ian G. *Religion and Science: Historical and Contemporary Issues.* San Francisco: HarperSanFrancisco, 1997.

The classic comprehensive introduction to the field. This revised and expanded edition of Barbour's Gifford Lectures deals with most aspects of the modern science and religion dialogue, and offers many reading suggestions. It also contains the famous fourfold typology of relating science and religion: conflict, independence, dialogue, and integration. Though it is mainly intended as an overview of the field, Barbour defends a "theology of nature" position coupled with a cautious use of process philosophy.

Clayton, Philip. *God and Contemporary Science.* Edinburgh: Edinburgh University Press, 1997.

This study in philosophical theology deals with contemporary scientific theories and their ramifications for theological views of God and divine agency. Clayton argues that naturalism can be countered by relating science and religion in a panentheist framework. As such, he argues for an 'emergentist supervenience' model of divine action.

Richardson, W. Mark, and Wildman, Wesley, J., eds. *Religion and Science: History, Method, Dialogue.* New York and London: Routledge, 1996.

This voluminous collection of essays considers the venture of building bridges between science and religion, both historically and methodologically (parts I and II). Part III is a collection of essays by prominent theologians and scientists trying to bring the major contemporary scientific theories into contact with theological doctrines. An extensive thematically structured list of suggested scientific and theological readings concludes this interdisciplinary book.

Southgate, Christopher, ed. *God, Humanity and the Cosmos: A Textbook in Science and Religion.* Harrisburg, Pa: Trinity Press, 1999.

This textbook surveys historical and philosophical aspects of relating science and religion, and highlights many facets of modern scientific theories. It also includes discussions on topics which are often left out, such as the relation between psychology and theology, science and education, Islamic perspectives, and issues of technology and ethics. The individual chapters are clearly structured into many subsections with many cross-references which makes the book usable not only for introductory courses on science and religion but also for self-study.

2. METHODOLOGY OF SCIENCE & RELIGION

Barbour, Ian G. *Myths, Models, and Paradigms: A Comparative Study in Science & Religion.* San Francisco: Harper & Row, 1974.

This book centers around three themes. The first is the different functions and internal logics of scientific and religious language. The second theme concerns the role of models in science and religion and their function for interpreting experience and restructuring our worldview. Thirdly the role of paradigms in science and religion is highlighted. Barbour concludes that both science and religion offer knowledge of reality based on experience. This work also offers the philosophical basics of so-called 'critical realism' in science and religion.

Drees, Willem B. *Religion, Science and Naturalism.* Cambridge: Cambridge University Press, 1996.

In this work, Drees adopts an explicitly naturalistic stance. Many theological issues are considered and critically analyzed according to a extensively outlined naturalist methodology. Drees concludes that a naturalist methodology has serious repercussions for the theological worldview as well as for religious anthropology. Drees sees religion embedded in our evolutionary history and our neurophysiological constitution, and values religious traditions as important for their wisdom and prophetic vision. He also raises the important issue of 'limit questions': the questions that science raises but cannot answer.

Gregersen, Niels H., and Van Huyssteen, J. Wentzel, eds. *Rethinking Theology and Science: Six Models for the Current Dialogue.* Grand Rapids, Mich.: Wm. B. Eerdmans, 1998.

In six essays an equal number of different models for relating theology and science are outlined. Van Huyssteen writes on postfoundationalism; van Kooten Niekerk presents a version of critical realism; Drees outlines naturalism; Herrmann expounds on a nonintegrative pragmatic approach; Watts writes on the complementarity between science and theology; and finally, Gregersen presents a contextual coherence theory that indicates that contact between theology and science takes place on several levels. Every approach tries to absorb the cognitive pluralism and counter relativist currents that threaten the science and religion dialogue.

Murphy, Nancey. *Theology for an Age of Scientific Reasoning.* Ithaca, NY and London: Cornell University Press, 1990.

Murphy's acclaimed book deals with the challenge of skepticism regarding Christian belief. Against the claims of the non- or irrationality of Christian belief over against the rationality of science, Murphy defends the view that religious belief is as rational as science. Murphy refers to Lakatos's methodology of scientific research programs arguing that religious reasoning is similar to scientific procedure. She tests the viability of her proposal by investigating actual theological research programs, such as Pannenberg's and Roman Catholic Modernism, concluding that theology makes claims to knowledge in the same way as science does.

Torrance, Thomas F. *Theological Science.* London: Oxford University Press, 1969.

Theology here is taken by Torrance, influenced by Barth, as the science of God. The methodological and epistemological issues connected with such a concept of theology commit theologians to a dialogue with other sciences and with philosophy, for they all use reason as the basic instrument, be it directed at different subject-matters. Science and theology nowadays share the same problem: how to attain knowledge of what goes beyond ourselves without imposing our presuppositions on reality. This book specifically deals with the methodological issues this problem raises for theology.

3. HISTORY OF SCIENCE & RELIGION

Brooke, John Hedley. *Science and Religion: Some Historical Perspectives.* Cambridge, UK: Cambridge University Press, 1991.

Brooke's work challenges the 'warfare' image of the history of the relation between science and religion by emphasizing contextual shifts. The essays contained in this volume all highlight specific historical periods in which science and religion interacted (such as the age of the Scientific Revolution and the Enlightenment) or specific issues on which science and religions (dis)agreed (such as the clockwork universe, natural theology, and evolutionary theory). Brooke links his historical reflections to the twentieth-century science and religion dialogue. An extensive bibliographical essay concludes this volume.

Funkenstein, Amos. *Theology and the Scientific Imagination: From the Middle Ages to the Seventeenth Century.* Princeton, N.J.: Princeton University Press, 1986.

This study addresses the transition from medieval to modern modes of thought. Funkenstein argues that the divine attributes of omnipresence, omnipotence, and providence contributed to but also underwent reinterpretation because of the emergence of the natural sciences. Due to the resultant theological and scientific changes, there arose in the seventeenth century a new ideal of knowledge: the ideal of knowledge-by-doing or knowledge by construction. Funkenstein argues that these developments eventually lead to the 'de-theologization' of science in Enlightenment thought.

Lindberg, David C., and Numbers, Ronald L., eds. *God & Nature: Historical Essays on the Encounter Between Christianity and Science.* Berkeley, Calif.: University of California Press, 1986.

These essays cover the periods of the Early Church, the Middle Ages and the controversy surrounding Galileo, the seventeenth century Scientific Revolution and the rise of Darwin's evolutionary theory, and contemporary debates concerning Creationism and the relation between present-day protestant theology and science. The essays attempt to counter the 'warfare' thesis, and show that a highly delicate historical account of the interplay between religion and science is possible.

White, Andrew Dickson. *A History of the Warfare of Science with Theology in Christendom.* London and New York: D. Appleton & Co., 1896.

Now generally regarded as one of the founding fathers of the so-called 'warfare'-thesis of religion and science, White sets out to describe the history of the relation between religion and science in terms of an age-old conflict. Evolutionary theory, geography and geology, astronomy, miracles and magic, archeology, anthropology and ethnology, history, meteorology, chemistry and physics, philology, psychology, politics and economy - all these domains are covered in the more than 900 pages of White's account of the battle between the religious and the scientific worldview.

4. PHYSICS & RELIGION

Barrow, John D. and Tipler, Frank J. *The Anthropic Cosmological Principle.* Oxford, UK and New York: Oxford University Press, 1986.

An astronomer and a physicist try to explain the relation between the properties of the universe and the existence of life. Covering the history of design arguments and teleological principles, as well as modern cosmology and astrophysics, the authors argue that modern physics and cosmology indicate that life is not accidental. They claim that modern science contains evidence for both the weak and the strong anthropic principles, stating that there is a close connection between the universe as it is and the emergence of carbon-based observers.

Davies, Paul. *God and the New Physics.* London: J.M. Dent & Sons, 1983.

Davies expounds on "the impact of the new physics on what were formerly religious issues," and concludes that "science offers a surer path than religion in the search of God." This book deals with physical, philosophical, and theological issues such as mind and soul, determinism and free will, and miracles. Davies reworked some of the controversial statements in this work in a sequel *The Mind of God: The Scientific Basis for a Rational World.* (New York etc.: Simon & Schuster, 1992).

Drees, Willem B. *Beyond the Big Bang: Quantum Cosmologies and God.* La Salle, Ill.: Open Court, 1990.

Without too many technicalities, Drees discusses issues at the interface of science and religion, such as: Does Big Bang cosmology have any relation to the Christian doctrine of creation *ex nihilo?* What does quantum cosmology state about 'the beginning' of the universe? Do the 'anthropic principles' have any scientific groundings? And how does eschatology fare in the light of the scientific cosmological futures? Some methodological reflections already foreshadow his naturalist position.

Russell, Robert John; Murphy, Nancey; and Isham, C.J., eds. *Quantum Cosmology and the Laws of Nature: Scientific Perspectives on Divine Action.* 2nd Edition. Berkeley, Calif.: CTNS and Vatican City State: Vatican Observatory, 1999.

A collection of interdisciplinary essays written by leading scientists, theologians, and philosophers of religion on the implications of quantum cosmology and the status of the laws of nature for theological and philosophical issues regarding God's action in the world. The essays are clustered into five sections: the scientific background of quantum cosmology, methodological remarks on relating science and theology, philosophical issues on time and the laws of nature, and two sections on theological implications.

Worthing, Mark William. *God, Creation, and Contemporary Physics.* Minneapolis, Minn.: Fortress Press, 1996.

Worthing's book surveys the links between theories from physics and cosmology and the theological issues of God's existence, creation out of nothing, and divine action. He also describes possible consequences of physical theories for Christian eschatology. The conclusion of the book is that theology cannot, strictly speaking, challenge the scientific conclusions drawn from the new physics, but theology must take notice of the metaphysical and theological implications of these theories.

5. BIOLOGY & RELIGION

Behe, Michael. *Darwin's Black Box: The Biochemical Challenge to Evolution.* New York: The Free Press, 1996.

Behe's book is one of the basic writings of the so-called 'Intelligent Design' movement. Behe argues that evolution takes place on the molecular level where science has shown that 'irreducibly complex' system exist: systems that cannot have evolved, but must have come into existence in one piece. Behe claims that the molecular basis of life is irreducibly complex, and, hence, cannot properly be described by the Darwinian evolutionary theory. Therefore, 'intelligent design' is the only plausible explanation for this irreducible complexity and for life.

Dembski, William A. *Intelligent Design: The Bridge Between Science & Theology.* Downers Grove, Il: InterVarsity Press, 1999.

In this book Dembski explains what the Intelligent Design movement is about: a scientific research program, anti-naturalistic, and a theology of divine action. Standing in the tradition of British natural theology, ID attempts to reinstate design within science, especially in the irreducible complexity of biological sciences. Dembski claims that by referring to empirically detectable signs of intelligent design, theology and science are able to provide epistemic support for each other's claims.

Durant, John, ed. *Darwinism and Divinity: Essays on Evolution and Religious Belief.* Oxford, UK: Basil Blackwell, 1985.

In seven interdisciplinary essays, historians, theologians, anthropologists, sociologists, and philosophers use their expertise to shed some light on the question how evolutionary thought affects religious belief. The essays are written from different perspectives, which results in a kaleidoscope of views instead of a unitary vision. The authors not only consider the impact of evolution on religious thought, but also ask how religion affected evolutionary thinking. Some of the essays deal explicitly with discussions surrounding creationism.

Haught, John F. *God After Darwin: A Theology of Evolution.* Boulder, Colo.: Westview Press, 2000.

According to Haught, the discussions between die-hard evolutionists like Daniel Dennett and Richard Dawkins and Christian apologists all rest on the same mistake: both groups focus too much on static design and (dis)order in the universe. Haught, on the other hand, emphasizes the dynamic aspects of creativity and novelty that emerge in the process of evolution. He shows how these aspects are compatible with a concept of God that is described in partly Teilhardian and partly process-theological terms.

Hefner, Philip. *The Human Factor: Evolution, Culture, and Religion.* Minneapolis, Minn.: Fortress Press, 1993.

This book aims "at a theological anthropology in the light of the natural sciences." Especially noteworthy is Hefner's hypothesis that humans are 'created co-creators' with God, which proved influential in the science and religion dialogue. This hypothesis, emphasizing the potentials of human beings, is the red line of the book. The five parts that make up this book contain theoretical reflections on science and religion, reflections on nature, freedom, culture (including ethics), and connections with theology.

Numbers, Ronald L. *The Creationists.* Berkeley, Calif.: The University of California Press, 1993.

Numbers provides a detailed history of creationist lines of thinking from Darwin on until the renewed interest since the 1960s in the US. He shows that many paradigm shifts have taken place within the creationist framework, specifically with regard to 'catastrophism,' the antiquity of the earth, and the geological interpretations of the Genesis Flood. Numbers also shows how creationism became institutionalized, and how the churches responded to creationist thought, and argues that creationism questions the integrity and meaning of science itself.

Peacocke, Arthur. *God and the New Biology.* London andMelbourne: J.M. Dent & Sons Ltd, 1986.

Peacocke sets out to describe how the perspective of the new biology, with its "increasing apprehension of the labyrinthine complexity of the molecular processes and structures that are involved in the dynamics of a living organism," relates to a new understanding of the interrelations between humans, evolution, and God. Taking the issue of reductionism as his starting point, Peacocke argues that the new biology shows nature to be multi-leveled and hierarchical with new emergent features developing all the time. He also discusses sociobiology and Dawkins' 'selfish gene' idea.

Ruse, Michael. *Can a Darwinian Be a Christian? The Relationship Between Science and Religion.* Cambridge: Cambridge University Press, 2001.

Evolutionary theory meets the Christian religion in this work by an eminent philosopher. The book does not treat the dialogue between science and religion on a general level, but shows how concrete Christian doctrines are confronted by evolutionary thought. Ruse argues against Intelligent Design and Creationism, and argues in favor of social Darwinism and sociobiology. He concludes that nothing precludes a Darwinian to be a Christian, though at times it may be challenging and difficult.

Russell, Robert John; Stoeger, William R.; and Ayala, Francisco J., eds. *Evolutionary and Molecular Biology: Scientific Perspectives on Divine Action.* Berkeley, Calif.: CTNS and Vatican City State: Vatican Observatory, 1999.

A collection of interdisciplinary essays written by leading scientists, theologians, and philosophers of religion on the implications of evolutionary and molecular biology for the concept of divine action. In four sections the authors deal with the scientific background of evolution and molecular biology; the relation between evolution and divine action; religious interpretations of biological themes; and the interrelations between biology, ethics, and the problem of evil.

Ward, Keith. *God, Chance & Necessity.* Oxford: Oneworld, 1996.

Ward argues against the scientistic and materialist claims like those of Richard Dawkins, Peter Atkins, and Michael Ruse who see the universe as governed by chance and not by purpose. Ward takes their claims seriously, but shows how these scientistic claims ultimately point in the direction of God's existence as the best available explanation. Though the book focuses on (neo-)Darwinian evolutionary theory, Ward also touches upon cosmology, the problem of entropy and emergence, and the mystery of consciousness.

6. MATHEMATICS, COMPUTER SCIENCE & RELIGION

Gell-Mann, Murray. *The Quark and the Jaguar: Adventures in the Simple and the Complex.* London: Little, Brown and Company, 1994.

Gell-Mann, a Nobel Prize-winning theoretical physicist, explores the relationships between various scientific concepts of simplicity and complexity. The central focus of the book is the notion of complex adaptive systems: systems that evolve and learn by acquiring information. Gell-Mann's account covers many terrains: quantum mechanics and the fundamental laws of physics, information theory, biological evolution, human creative thinking, and ecology.

Gregersen, Niels Henrik, ed. *From Complexity to Life: On the Emergence of Life and Meaning.* Oxford/New York: Oxford University Press, 2002.

In the three parts that make up this book the link between complexity and information, the origin of life, and the nature of the universe is investigated. Complexity scientists, theologians, and philosophers of religion explore questions of defining complexity, the nature and role of information in physics and biology, and philosophical and religious perspectives on the meaning of emergence and complexity.

Herzfeld, Noreen L. *In Our Image: Artificial Intelligence and the Human Spirit.* Minneapolis, Minn.: Fortress Press, 2002.

This book charts some of the consequences of the sciences of Artificial Intelligence for our idea of what it means to be human, and how AI affects the phrase that we are created in God's image. Dealing with these and related issues, Herzfeld develops a model of relationality: "The way we define God's image in our human nature or our image in the computer has implications, not only for how we view ourselves but also for how we relate to God, to one another, and to our own creations."

Puddefoot, John. *God and the Mind Machine: Computers, Artificial Intelligence and the Human Soul.* London: SPCK, 1996.

Issues surrounding computers, life, intelligence, and the human soul are the focus of this book. It addresses the question of how to relate theology to issues concerning computer science and Artificial Intelligence. This book addresses the growing anxiety among religious believers that developments in computer science and Artificial Intelligence will take away the soul. Puddefoot argues that these scientific developments might be seen as part of God's purpose with the universe. Though Puddefoot draws no definite conclusions, his study does give impetus to further explorations and reflections.

Russell, Robert John; Murphy, Nancey; and Peacocke, Arthur R., eds. *Chaos and Complexity: Scientific Perspectives on Divine Action.* Berkeley, Calif.: CTNS & Vatican City State: Vatican Observatory, 1995.

A collection of essays of eminent scientists, theologians, and philosophers of religion on the implications of chaos and self-organization in physical, chemical, and biological systems for philosophical and theological issues regarding divine action in the world. The first section contains two introductory essays on the scientific aspects of chaos and complexity. The second relates chaos and complexity to the philosophy of life. The third and fourth sections link chaos and complexity to divine action and explore alternative approaches of divine action. The whole constitutes a detailed overview of the contemporary reception of the sciences of nonlinear systems in theological reflection.

Smith, Peter. *Explaining Chaos.* Cambridge: Cambridge University Press, 1998.

This volume is a mildly technical introduction to the concepts of chaos theory and its philosophical implications. It is especially noteworthy that Smith makes a distinction between the mathematics of chaos and its empirical applications. Fractals, the problem of predictability and explanation, the difference between chaos and randomness, and the definition of chaos - these are only a few of the many issues that Smith covers.

7. THE HUMAN SCIENCES & RELIGION

d'Aquili, Eugene and Newberg, Andrew B. *The Mystical Mind: Probing the Biology of Religious Experience.* Minneapolis, Minn.: Fortress Press, 1999.

D'Aquili and Newberg attempt to integrate theology and neuroscience by exploring "the issue of how 'ultimate being' is perceived and experienced by the human brain and mind." The authors introduce basic concepts from theology and neuroscience, and explore the role of the brain and mind in myth-making, ritual and liturgy, meditation, near-death experiences and mysticism. Both Eastern and Western religious traditions are taken into account. Finally, they try to integrate their findings into a phenomenological 'neurotheology.'

Austin, James H. *Zen and the Brain: Toward an Understanding of Meditation and Consciousness.* Cambridge, Mass.: MIT Press, 1998.

Meditation and neurology are brought together in an attempt to unravel the mystery of consciousness and enlightenment or 'peak' experiences. Austin takes Zen meditation as his starting point, and describes the physiological mechanisms involved. Thereafter he summarizes some of the latest developments in brain research and defines the usual states of consciousness and their alternative expressions. Finally alternate meditative states of consciousness as well as enlightenment experiences are investigated.

Brown, Warren S.; Murphy, Nancey; and Malony, Newton H., eds. *Whatever Happened to the Soul? Scientific and Theological Portraits of Human Nature*. Minneapolis, Minn.: Fortress Press, 1998.
This interdisciplinary volume contains ten essays by scientists and theologians on scientific and theological aspects of human nature. Special focus is on the idea of the soul. Many authors adopt the position of 'nonreductive physicalism,' a holistic or monistic view over against a dualist view of mind and brain. From this perspective the soul is described as "a functional capacity of a complex physical organism."

Mithen, Steven. *The Prehistory of Mind: The Cognitive Origins of Art, Religion and Science*. New York: Thames and Hudson, 1996.
Mithen's book is a mixture of an archeological account of the prehistoric roots of our minds, connected to the emergence of art and religion, and a study in the philosophy of mind, seeing in the archeological data evidence for the modularity of the human brain. Mithen argues there is a common origin to art, religion, and science in the prehistoric usage of the mind, which led, through a series of evolutionary phases of specialization and collaboration, to our modular minds.

Palmer, Michael. *Freud and Jung on Religion*. London/New York: Routledge, 1997.
Today's psychology is still very much indebted to the two founding fathers of twentieth-century psychology, Sigmund Freud and Karl Gustav Jung. Their relation to religion is often interpreted in ambiguous fashion: Freud as a reductionist enemy of religion, and Jung as a New Age enthusiast. In this volume, Palmer goes back to the basics of Freud's and Jung's own writings on the psychology of religion, linking their claims on religion to their psychological theories, and drawing comparisons between their respective positions whilst critically evaluating their claims.

Peters, Ted. *Playing God? Genetic Determinism and Human Freedom*. New York and London: Routledge, 1997.
Thinking about genetics is closely bound to problems of determinism and human freedom. According to Peters, a cultural expression of this is the 'gene myth,' which asserts that everything that makes us distinctively human is genetically determined. Peters confronts this myth with the theological view of humans as future-oriented and as co-creative with God. This view will lead to a healthy ethics for guiding genetic research which should be used "to relieve human suffering and to make this a better world in which to live."

Rolston, Holmes, III. *Genes, Genesis and God: Values and their Origins in Natural and Human History*. Cambridge: Cambridge University Press, 1999.
Based on Rolston's Gifford Lectures, this study explores the connections between religion, ethics, and biological accounts of genetic influences. Rolston strongly argues against sociobiological accounts that reduce religion and ethics to biological features. He interprets evolutionary history as the genesis and history of natural values, which are conserved and transmitted by science, religion, and ethics. He claims that the sociobiological reductionists miss an important point by misunderstanding how these values are transmitted and shared. As such, Rolston assigns a prominent role to culture, and accordingly links 'nurture' intimately with 'nature.'

Russell, Robert John; Murphy, Nancey; Meyering, Theo C.; and Arbib, Michael A. eds. *Neuroscience and the Person: Scientific Perspectives on Divine Action*. Berkeley, Calif.: CTNS and Vatican City State: Vatican Observatory, 1999.
Another collection of essays written by scientists, philosophers, and theologians ranging the broad terrain of the cognitive neurosciences and their implications for philosophy, theology, and models of divine action. Many essays revolve around the issues of the sense of self and soul, the person, and religious anthropology. One can find also philosophical accounts on the relation between mind and brain, theories of supervenience, emergence, and Artificial Intelligence.

8. FEMINIST APPROACHES TO RELIGION & SCIENCE

Haraway, Donna J. *Modest Witness, Second Millennium. FemaleMan© Meets OncoMouse™: Feminism and Technoscience*. New York and London: Routledge, 1997.
A study on the many facets of technoscience and their implications for our view of the world, and for feminism in particular. Haraway argues that the information sciences and the technological applications for the life sciences are changing our view of reality and of ourselves, and she specifically explores the idea of 'cyborgs,' beings that are part human part machine. She further reflects on the changing values and ethical aspects of technoscience.

Harding, Sandra. *Whose Science? Whose Knowledge? Thinking from Women's Lives*. Cornell: Cornell University Press, 1991.
A variety of contemporary voices from many different perspectives criticizes mainstream science and technology. This study links the feminist criticisms on Western science, technology, and epistemology to these other perspectives. Two red lines run through the ten essays contained in this book. First, the evaluation of interrelations between science, models of knowledge and the Western society and culture, and the creation of 'others' which are outside the mainstream society or culture. Secondly, Harding tries to show how feminisms are influenced by and influencing other liberatory movements.

Tuana, Nancy. *The Less Noble Sex: Scientific, Religious, and Philosophical Conceptions of Women's Nature.* Bloomington/Indianapolis: Indiana University Press, 1993.

Tuana argues that religion and philosophy have affected and have been influenced by scientific theories of women's nature and her inferiority to man. The book gives a historical account of these matters from the classical period until the nineteenth century. The central claim is that the belief "that woman is less than man … is more than simple bias, easily amenable to revision. It is part of our inherited metaphysics." Exposing metaphysical assumption will benefit critical reexamination and openness to alternatives.

Wertheim, Margaret. *Pythagoras' Trousers: God, Physics, and the Gender Wars.* New York: Norton, 1997.

Wertheim explores the history of the interconnections between science and the wider cultural sphere. Her claim is that the relation between science and religion is more intimate than is often thought. Under the influence of the idea of a heavenly realm of mathematics, scientists, and especially physicists, received in our Western society a priest-like status. As Wertheim argues, this 'priestly' nature of science is also largely responsible for the masculine character of many sciences, and for the difficulties that women experience when they want to participate in this culture.

9. PHILOSOPHY, SCIENCE & RELIGION

Clayton, Philip. *Explanation from Physics to Theology: An Essay in Rationality and Religion*. New Haven and London: Yale University Press, 1989.

Does religion give explanations similar to scientific explanations? To find an answer to this question, Clayton investigates the nature and justification of explanatory claims in both the natural and the social sciences, and argues that when the concept of explanation is not reduced to merely scientific explanation, religious experiences and beliefs can appropriately be said to function as explanations. The upshot is that the function of religious and scientific explanations are comparable.

Pannenberg, Wolfhart. *Theology and the Philosophy of Science.* Philadelphia: Westminster Press, 1976.

This volume explicitly addresses the issue whether or not theology is a science. Pannenberg gives detailed expositions of theology's struggles with Logical Positivism, and Positivism's struggle with the critical rationalism of Popper. He also considers the relation between the natural and social sciences, and the role of hermeneutics. Ultimately, Pannenberg argues that theology is a science: the 'science of God,' whilst doctrines could be considered as hypotheses.

Stenmark, Mikael. *Rationality in Science, Religion, and Everyday Life: A Critical Evaluation of Four Models of Rationality.*Notre Dame, Ind.: University of Notre Dame Press, 1995.

In this study, Stenmark distinguishes four models of rationality and discusses what these models entail especially for science, religion, and our everyday life. Instead of employing an abstract model of rationality and attempting to incorporate these three areas, Stenmark opts to start with rationality as practice-oriented and as mirroring actual human practices. This leads him to his 'presumptionist' model of rationality: in both science and religion it is rational to accept a belief unless there are good reasons to abandon it.

Stenmark, Mikael. *Scientism: Science, Ethics and Religion*. Aldershot etc.: Ashgate, 2001.

In the first chapter, Stenmark provides an impressive overview of the different kinds of 'scientism,' basically the view that there is nothing "outside the domain of science nor any area of human life to which science cannot successfully be applied." In subsequent chapters Stenmark attempts to debunk scientistic claims with regard to knowledge and reality, morality and ethics, and religion. He concludes that scientism is a metaphysical belief akin to religious belief, and urges scientists to become more conscious of the limitations of the scientific enterprise.

van Huyssteen, J. Wentzel. *The Shaping of Rationality: Toward Interdisciplinarity in Theology and Science.* Grand Rapids, Mich.: William B. Eerdmans Publishing Company, 1999.

Van Huyssteen explores possibilities of interdisciplinary dialogue between theology and science based on mutual respect and understanding. He tries to steer away from both extremes of modernist foundationalism and postmodernist relativism by developing a *postfoundationalist* position which emphasizes contextuality, embedded experience, and the 'transversal' potentiality of rationality to reach beyond the confines of the local community. Van Huyssteen emphasizes the specific rationality of theology over against scientistic, foundationalist, and relativist tendencies in modern philosophy of science and the broader culture.

10. THEOLOGY & THE SCIENCES

Allen, Diogenes. *Christian Belief in a Postmodern World: The Full Wealth of Conviction.* Louisville, Ky.: Westminster John Knox Press, 1989.

Allen is of the opinion that the Enlightenment has expelled God from the world, while faith has been reduced to either fideism of relativism. However, now that we have seen the decline of the Enlightenment project, there may be new possibilities for faith to experience God. In an attempt at rediscovering the riches of the Christian faith, Allen describes how the order of nature can be seen as a witness to God's existence. He also highlights the reasonability of faith and revelation, divine action, and the issue of other faiths.

Nasr, Seyyed Hossein. *Religion and the Order of Nature.* New York and London: Oxford University Press, 1996.

Although the focus of this work is mainly on Western religious interpretations of nature and the interplay between religion, science, and philosophy, Nasr explicitly invokes other religious traditions as well, especially the Islamic tradition. In a blend of historical, philosophical, and religious writing, Nasr tries to indicate how the different religious traditions embody wisdom that can help overcome the contemporary ecological crises, while establishing a new religious worldview based on the re-sacralization of nature.

Peacocke, Arthur. *Theology for a Scientific Age: Being and Becoming - Natural, Divine and Human.* London: SCM Press, 1993.

In this book, based on his Gifford Lectures, Peacocke explores the implications of the sciences for theological doctrine. Focusing on the concept of God, God's interaction with the world, and God's communication with humanity through Jesus Christ, he constructs a panentheist framework in which the world is seen as a many-leveled emergent whole governed by the dynamic interplay of chance and necessity.

Peters, Ted. *God as Trinity: Relationality and Temporality in Divine Life.* Louisville, Ky.: Westminster/John Knox Press, 1993.

The Christian doctrine of the Trinity is explored in relation to some contemporary issues in theology and science. Peters gives an introduction to 'Trinity Talk,' and addresses some contemporary moral and theological issues. He also gives an overview of the trinitarian views of several twentieth-century theologians. Finally, relations to philosophy and science, especially regarding temporality, are explored.

Polkinghorne, John, ed. *The Work of Love: Creation as Kenosis.* Grand Rapids, Mich.: William B. Eerdmans and London: SPCK, 2001.

'Kenosis' or the self-limitation of God has increasingly gained attention. It refers to the idea that God voluntarily limited his power so as to allow for freedom for finite creatures. In the essays collected in this volume, eleven well-known theologians explore this notion, especially in connection with the doctrine of creation, the relation between humans and nature, divine action, and our scientific worldview.

Polkinghorne, John, and Welker, Michael, eds. *The End of the World and the Ends of God: Science and Theology on Eschatology.* Harrisburg, Pa.: Trinity Press International, 2000.

The contributions in this interdisciplinary volume center around the question how our contemporary culture influences and is influenced by theological ideas about the end of the world. The essays are clustered in four sections as reflections on eschatological themes from the natural sciences, the cultural sciences and ethics, biblical studies, and from systematic theology. Some central themes are the relation between scientific cosmology and eschatology, the role of culture and the church as cultural space, the concept of time and the future, eschatological themes in the Bible, and the issue of life after death.

Polkinghorne, John. *The Faith of a Physicist: Reflections of a Bottom-Up Thinker.* Minneapolis, Minn.: Fortress Press, 1996.

Structured according to the Nicene Creed, Polkinghorne's Gifford Lectures explores "to what extent we can use the search for motivated understanding, so congenial to the scientific mind, as a route to being able to make the substance of Christian orthodoxy our own." Polkinghorne discusses how science bears upon specific theological doctrines like creation, christology, pneumatology, and eschatology.

Qadir, C.A. *Philosophy and Science in the Islamic World.* New York: Croom Helm, 1988.

Historically speaking, the Western civilization owes much to Islamic influences, due to the translations of Greek and Arabic texts on science and philosophy. In this work, Qadir narrates the emergence, rise, decline, and the rediscovery of Islamic philosophy and science. He argues that the Islamic perspective emphasizes the wholeness and oneness of the cosmos and of our knowledge. In the final three chapters, the contemporary rediscovery of the Islamic potentials concerning philosophy, science, and technology in Muslim countries is described.

Samuelson, Norbert. *Judaism and the Doctrine of Creation.* Cambridge: Cambridge University Press, 1994.

Expounding historical, religious, and philosophical aspects of some Jewish perspectives on the doctrine of creation, Samuelson discusses the interrelations between the Hebrew scriptures, Greek and Jewish philosophy, and contemporary physics. Some reflections can be found on Rosenzweig's philosophy, the limits of human reason and religious faith, the character of religious belief, the relevance of scientific models to religious doctrine, and the nature of the relationship between God and the universe.

Ward, Keith. *Religion & Creation.* Oxford: Clarendon Press, 1996.

This book contains a thorough analysis and comparison by a Christian theologian of the doctrine of creation and the notion of God in four scriptural traditions, and its interpretation by eminent twentieth-century theologians within those traditions. Ward concludes that there are many fruitful comparisons to be made regarding the properties which are ascribed to God in the different traditions. In the final part of the book, Ward makes explicit "a specifically Christian doctrine of God as Trinity, in the light of the new perspective on the universe which modern cosmology provides."

11. SCIENCE & DIVINE ACTION

Polkinghorne, John. *Science and Providence: God's Interaction with the World*. Boston: Shambala, 1989.

In this book, Polkinghorne addresses issues surrounding the question how we can reconcile the scientific worldview with the Christian's belief in a personal and caring God. Through exploring the relation between embodiment and action, Polkinghorne arrives at a model of divine action wherein God is seen to interact with the world by top-down action. The reference to chaos theory, which he explored further in many subsequent writings, has become the hallmark of Polkinghorne's theology of divine action.

Morris, Thomas V., ed. *Divine and Human Action: Essays in the Metaphysics of Theism*. Ithaca, NY and London: Cornell University Press, 1988.

The twelve diverse essays collected in this volume all revolve around the theological, philosophical, and metaphysical issues surrounding the relation and interaction of God with the created world and its inhabitants. These issues include divine causality and the natural world, providence, creaturely freedom and the role of chance, and the nature and properties of God. As the title indicates, the essays particularly address the traditional theist idea of God.

Tracy, Thomas F., ed. *The God Who Acts: Philosophical and Theological Explorations*. University Park, Pa: The Pennsylvania State University Press, 1994.

This collection of essays of renowned philosophers and theologians deals explicitly with the moral implications and difficulties surrounding divine action. The essays focus on two themes. First particular divine action is considered, especially related to the problem of evil. Secondly, the attention turns to universal divine action in connection with creation and human freedom.

Ward, Keith. *Divine Action*. London: Collins, 1990.

Ward tackles in clear arguments many difficult issues connected with the concept of divine action, such as the order of the universe, miracles, the problem of evil, and prayer. He argues that science has declared the death of the closed universe. Our universe turns out to be emergent and open, and God is personally and continually active in it, though his influence is undetectable for creatures. The life, death, and resurrection of Jesus of Nazareth constitutes "a definite embodiment of God's own activity for human redemption, which is the matrix for interpreting the Divine activity everywhere."

Wiles, Maurice. *God's Action in the World: The Bampton Lectures for 1986*. London: SCM Press, 1986.

In this work the famous though controversial 'single act' theory of divine action is expounded. Wiles shows how evil and suffering pose insurmountable problems for any interventionist view of divine action. This leads him to propose the idea that "the whole process of bringing into being of the world, which is still going on, needs to be seen as one action of God." Arguing from this model he deals with problems of evil, providence and Christology.

12. SCIENCE, RELIGION, & ETHICS

Barbour, Ian G. *Ethics in an Age of Technology: The Gifford Lectures, 1989-91, Vol. 2.* San Francisco: HarperCollins, 1992.

In this second volume of Gifford Lectures, Barbour addresses the ethical issues related to our use of applied science and technology. The book is structured in three parts. The first part deals with the different views on technology, human, and environmental values. In the second part, three 'critical' technologies, agriculture, energy, and computers are explored. In the third part, reflecting on the future use and development of technology, Barbour makes clear how the values discussed in the former two parts are relevant for technological policy decisions.

Murphy, Nancey, and Ellis, George F.R. *On the Moral Nature of the Universe: Theology, Cosmology, and Ethics*. Minneapolis, Minn.: Fortress Press, 1996.

How do science, theology, and ethics relate to each other? And does our understanding of the universe have any ethical implications? These are the questions that are explored in this study by a theologian and a cosmologist. Taking the integrity of the natural order as a starting point, the authors argue that God's action entails refusal to violate that order. This 'kenotic' view of God's action then is taken as having moral implications for a self-renunciatory ethic, "according to which one must renounce self-interest for the sake of the other, *no matter what the cost to oneself*."

Rolston, Holmes, III. *Environmental Ethics: Duties to and Values in the Natural World*. Philadelphia: Temple University Press, 1988.

Rolston defends the view that humans have to respond to and are responsible for nature. As such, he develops a theory of naturalist environmental ethics based on duties and values, which also seeks to optimize human fitness on earth and to do this in a moral manner. This theory is then applied to social, public, and business policy making. Many examples help to elucidate Rolston's points.

TAEDE A. SMEDES

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