Descartes' Natural Philosophy

Edited by

Stephen Gaukroger, John Schuster and John Sutton

London and New York

Descartes' Natural Philosophy

The most comprehensive collection on Descartes' scientific writings ever published, this volume offers a detailed reassessment of his scientific work and its bearing on his philosophy. Written by some of the world's leading scholars, the book focuses on Descartes as a pioneer of the mechanical philosophy, and practitioner of mathematics, mechanics, optics, anatomy, physiology and psycho-physiology.

The collection looks at Descartes' work in the sciences as an aspect of his natural-philosophical agenda. Among the key topics examined are:

- Descartes' novel contributions to mechanics, optics, and cosmology
- the central place of medicine in his overall project
- the connections between his investigations of specific psychological capacities and his ethics of self-government
- the debates and controversies into which he and his followers were drawn, and their role in shaping Cartesian natural philosophy.

By placing natural philosophy, rather than a sceptically driven epistemology, at the centre of Descartes' concerns, this book subjects many central themes in Cartesian philosophy to fundamental reassessment. It will therefore be of vital interest to all historians of philosophy or science.

Stephen Gaukroger is Professor of History of Philosophy and History of Science, University of Sydney.

John Schuster is Senior Lecturer in Science and Technology Studies, University of New South Wales.

John Sutton is Lecturer in Philosophy, Macquarie University.

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Contributors

Peter Anstey is a Research Fellow, Department of Philosophy, University of Sydney.

Jean-Robert Armogathe is Professor of the History of Religious and Scientific Ideas in Modern Europe, École Pratique des Hautes Études, Sorbonne.

Gordon Baker is a Fellow of St. John's College, Oxford.

David Behan is Professor of Philosophy, Agnes Scott College, Decatur, Georgia.

Annie Bitbol-Hespériès is attached to the Continuing Education section, Sorbonne.

Desmond Clarke is Professor of Philosophy, University College, Cork.

Betsy Newell Decyk is Lecturer in Philosophy and Psychology, California State University, Long Beach.

Dennis Des Chene is Associate Professor of Philosophy, Emory University.

Véronique M. Fóti is Associate Professor of Philosophy, Pennsylvania State University.

Daniel Garber is Professor of Philosophy, University of Chicago.

Stephen Gaukroger is Professor of History of Philosophy and History of Science, University of Sydney.

Peter Harrison is Associate Professor of Philosophy, Bond University.

Gary Hatfield is Professor of Philosophy, University of Pennsylvania.

Trevor McClaughlin is Senior Lecturer in History, Macquarie University.

Peter McLaughlin is Lecturer in Philosophy, University of Konstanz.

Katherine Morris is a Fellow of Mansfield College, Oxford.

Alberto Guillermo Ranea is Professor of History of Science and Technology, Universidad Torcuto Di Tella, Buenos Aires.

Timothy J. Reiss is Professor of Philosophy, New York University.

Peter Schouls is Professor of Philosophy, Massey University.

John A. Schuster is Senior Lecturer in Science and Technology Studies, University of New South Wales.

Dennis L. Sepper is Professor of Philosophy, University of Dallas.

Peter Slezak is Senior Lecturer in the School of Science and Technology Studies, University of New South Wales.

John Sutton is Lecturer in Philosophy, Macquarie University.

Yasuhiko Tomido is Professor of Philosophy, Kyoto University.

Klaas van Berkel is Professor of History, University of Groningen.

Theo Verbeek is Professor of Philosophy, University of Utrecht.

Catherine Wilson is Professor of Philosophy, University of British Columbia.

Celia Wolf-Devine is Associate Professor of Philosophy, Stonehill College, Mass.

John P. Wright is Professor of Philosophy, Central Michigan University.

John Yolton is Emeritus Professor of Philosophy, Rutgers University.

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References to Descartes' works

References to Descartes' works are to the standard edition: Charles Adam and Paul Tannery (eds.), *Oeuvres de Descartes,* 2nd. edn (11 vols., Paris, 1974–86). The edition is abbreviated to AT throughout, and reference is made to volume number and page number by Roman and Arabic numerals respectively, e.g. AT iv. 123. In the case of the *Principia* and the *Passions*, however, references are to Part and Article number, since this is a more convenient way of locating the relevant passage. Descartes' works are referred to by their original titles, in the original language.

A number of Descartes' natural-philosophy works are missing from, or appear only in a truncated form in what is now the standard English translation of Descartes' works: John Cottingham et al, *The Philosophical Writings of Descartes* (3 vols., Cambridge, 1984–91). Full English translations of the major works missing from this edition can be found as follows:

La Dioptrique, *Les Météores*, *La Géométrie* in Paul J. Olschamp (trans.), *René Descartes: Discourse on Method, Optics, Geometry, and Meteorology* (Indianapolis, 1965).

Principia Philosophiae in V.R. and R.P. Miller (trans.), *René Descartes: Principles of Philosophy* (Dordrecht, 1991).

Le Monde, *L'Homme*, *Description du Corps Humain* in Stephen Gaukroger (trans.), *Descartes, The World and Other Writings* (Cambridge, 1998).

Introduction

This volume gathers together a number of new studies of Descartes' natural philosophy. We have not concerned ourselves with the textbook image of Descartes in philosophy or the history of ideas, as father of modern philosophy, or as the inventor of modern epistemology, mind/body dualism, or advocate of a universal method. Rather, we focus on Descartes in the context of his times as a pioneer of the mechanical philosophy and leading practitioner of mathematics and a number of the then existing specialised traditions of scientific endeavour, such as mechanics, optics, anatomy, and physiology (including psycho-physiology). We view Descartes, moreover, as a natural philosopher whose aims and agendas were not independent of the social and intellectual contexts within which he was working; and as someone who, over time, not only achieved numerous remarkable successes, but who also endured several deflections of aim, tactical retreats and outright failures.

The theme of our volume is not entirely new. In recent years a small but growing body of research has examined aspects of Descartes' natural philosophy as part of a reassessment of his role in the history of Western thought. Our aim here is to represent and consolidate some of the present concerns in the area of Descartes' natural philosophy and to bring to light a number of new possibilities for its study. How these aims are viewed will inevitably depend in large measure upon how the term 'natural philosophy' is understood, both in general, and in the particular case of Descartes.

The term 'natural philosophy' has often been used, particularly in the literature in the history of science, in two ways: either it is used in an anachronistic way as a synonym for 'science' – an anachronism, since 'science' as a term denoting the presumed unity, methodological and institutional, of all inquiry into nature, is a nineteenth-century coinage. Or, with more justification it is used as a synonym for 'the sciences', meaning the set of narrower traditions of intellectual practice that existed in the early modern period on the basis of classical models, such as astronomy, optics, mechanics, anatomy, music theory, and the like. Strictly speaking, however, in the early modern period the term 'natural philosophy' denoted attempts to explain in a systematic way the nature of matter, the cosmological structuring of that matter, the principles of causation and the methodology for acquiring or justifying such natural knowledge. The dominant genus of natural philosophy – and the exemplar for its form, content, and the grammar of articulation – was, of course, Aristotelianism in various neo-scholastic guises, but the term similarly applied to challengers and alternatives of similar scope and aim; that is, to any particular species of the various competing genera: neo-Platonic, mechanistic (as in Descartes' work) or, later, Newtonian.

The construction of any particular natural philosophy in the early modern period was complicated by three further sets of considerations. First, each natural philosophy had to make out discursive linkages or articulations to matters of theological, political, and pedagogical interest, as well as, increasingly, to matters pertaining to the status and content of the practical arts. The patterning of these linkages went a long way to defining the character of a particular natural philosophy, and can reveal a great deal about the aims and interests of its author and the contextual forces to which he was responding.

Second, each natural philosopher had to consider the set of narrower traditions of science-like practice which existed at the time, such as astronomy and anatomy, setting priorities and possibly exclusions amongst them, and linking them conceptually to his natural philosophy. This too created a pattern of discursive linkages characteristic of a particular natural philosophy. Natural philosophers competed for status and precedence, and part of that competition involved attempts to co-opt and direct the practice of the already existing traditions of scientific endeavour. The practice of a subordinate science under the aegis of a particular natural philosophy was coloured by the nature of the conceptual linkage involved, as in Descartes' manner of mechanising physiology or optics. However, the macro-history of such sub-fields obviously eluded the control of any given natural philosophy and consisted in the interplay and concatenation, over time, of the ways it was linked to, and thus practised under, competing natural philosophies. The larger history of physiological or optical inquiry would show this character in the early modern period, with Descartes' interventions shaping moments in the process.

Finally, natural philosophising constituted an evolving sub-culture. Institutionalised Aristotelianism faced a host of challengers and the fate, as well as the meaning, of any particular natural philosophy was in the hands of its proponents and adversaries as the process of cultural bidding and competition unfolded over time. In this connection it should be noted that a natural philosophy did not have to exist in an explicit, frozen, systematised form. In any case the degree to which a natural philosophy had become consolidated, and the legitimacy of this consolidation were open to challenge, debate and negotiation. Nothing in fact prevented an individual natural philosopher from offering differently systematised natural philosophies (or versions of the 'same' natural philosophy) in different circumstances. Descartes notoriously did this, there being considerable differences between the mechanism of *Le Monde* and that of the *Principia* in terms of attempted metaphysical grounding, pedagogical systematisation, and articulation of fundamental concepts. All this points to the shaping of particular natural philosophies by local circumstances and their character as continually renegotiated cultural entities. Indeed many scholars would now acknowledge that the struggles over natural philosophies, which entrained and coloured struggles within the narrower traditions of scientific practice as well, defined the rhythms and moments in that process usually termed the 'Scientific Revolution' of the seventeenth century.

It follows from our perspective, as well as from recent developments in the literature, that neither Descartes' natural philosophy, nor anyone else's, could be produced by applying a universal method, or 'deduced' from metaphysics. Many modern scholars now hold that, although Descartes himself may have believed in the efficacy of his method (at least until it met severe difficulties in the late 1620s), grand, set-piece doctrines of scientific method such as Descartes' cannot and do not control and guide the actual practice in any given field of research, let alone the entire gamut of disciplines. Descartes' technical achievements in mathematics and the sciences cannot therefore be explained as applications of his method, nor can use of his method explain the complex and shifting architecture of his natural philosophy.

Similarly, it is now virtually impossible to believe Descartes deduced his entire system of natural philosophy from metaphysical principles. This folklore arose from the deductivist tone of Descartes' abortive method and from some of his more offhand public and private statements about the issue. It is clear that in his mature work, after abandoning the *Regulae* in 1628, Descartes increasingly came to see that neither the details of particular explanatory models, nor the facts to be explained, could be deduced from metaphysics. In the *Principia* his position became very clear: we may know with certainty from metaphysical deduction that the essence of matter is extension, but we cannot deduce from this truth more detailed explanatory mechanistic models for such phenomena as gravity, light, magnetism, planetary motion, sensory perception and animal locomotion. The best one can say is that such models should not contradict metaphysically derived certainties and that relevant facts must also be considered in shaping explanatory models. Hence, such lower-level models are necessarily hypothetical and can achieve at best only 'moral certainty'.

Given all this, our approach to Descartes' natural philosophy may be termed dynamic rather than static, a perspective shared by most of the papers included in the collection. By this we mean that Descartes' natural philosophy, including his work in the subordinate domains of practice, was continually in process, contested and negotiated during his life and after his death. This is not to say that Descartes lacked systematising aims or failed to pursue them; rather, it means that we do not believe he ever finally espoused one temporally frozen system, let alone a system deducible from metaphysics or method. To study Descartes' natural philosophy is thus to study his natural-philosophising: his various attempts at systematic explanation of matter, cosmos, causation and method in relation to his practice of those more narrow science-like traditions particularly favoured by him, such as optics, statics and hydrostatics, music theory, anatomy, and physiology. It also necessarily involves the study of his situationally shaped attempts, over time, to enrol followers, marginalise competitors, and defeat opponents, as well as the continuation of these processes by his supporters and detractors, even after he had vanished from the natural-philosophical scene.

Many of the contributions to the collection pay much greater attention to Descartes' immediate predecessors, contemporaries, and immediate successors than is usual. The first is important because we must understand the context in which Descartes' work began: what tradition bequeathed to his generation as problems, techniques, and solutions. The second is important because we need to know how Descartes' contemporaries understood and reacted to his natural philosophy if we are to reach a better sense of just what was at issue for Descartes. What exactly his immediate successors took up, and why they took up what they did, is also of critical importance because twentieth-century understandings of Descartes often bear little relation to how he was interpreted before the twentieth century. This is nowhere more striking than on questions of cognition and the nature of the mind, for Descartes was generally taken as a dangerous materialist from the mid-eighteenth to the end of the nineteenth century, and as the antithesis of a materialist from then on. Paramount among influential modern caricatures of Descartes are Gilbert Ryle's *Concept of Mind* (1949) – with its idea of the Cartesian mind as 'the ghost in the machine', a mysterious spiritual being somehow concealed within a robotic exterior, implicated in a bewildering bifurcation of inner and outer lives – and Richard Rorty's account in *Philosophy and the Mirror of Nature* (1980), whereby philosophy has since Descartes become divorced from questions of practical, moral, and political importance through its arid attempts to ward off epistemological scepticism.

Much of the misunderstanding that lies behind these kinds of account comes from a refusal to take the category of natural philosophy seriously, or even to take any notice of it at all. A distinction between philosophy and science, although it has often been recognised as problematic (especially in the last twenty years), has dominated twentieth-century thinking. This distinction has been applied to physical theory, separating out the properly metaphysical/epistemological/methodological bits from the properly scientific bits, and to cognition, where it has motivated a separation between those questions appropriate to empirical psychology and neurophysiology, and those appropriate to epistemology. The result is the carving up of questions and domains which, for Descartes and other seventeenth-century thinkers, were part of an integrated project, so that something that made perfectly good sense and had a clear rationale now becomes at best problematic and at worst indefensible.

If one takes the category of natural philosophy seriously, however, we are forced to recognise a number of themes cutting across his project which ultimately must be brought together. These include: his technical work in the various sciences as a function of his natural-philosophical agenda, including especially his little-studied deep concern with anatomy and physiology; his insistence on the central place of medicine in his overall project; the connections between his detailed investigations of specific psychological capacities and his developing ethics of self-government and the management of the passions; the associated, previously almost unexamined issue of his strategies for the organisation and supervision of empirical and experimental evidence; the contrast between his formal doctrine of method, used rhetorically in the presentation of his work, and his actual working styles and techniques in natural philosophy and the subordinate sciences; the links between his theorising about the idiosyncratic dynamics at the basis of his mechanical philosophy and his work in optics and mechanics; his early aims and techniques in natural philosophising; the debates and controversies into which he and his later followers were drawn, and their effects in shaping Cartesian natural philosophy.

The overall thrust of the view of Descartes' natural philosophy presented in the essays in this volume is of something dynamic, something that changes both in response to internal developments and in response to external pressures which shape the milieu in which Descartes pursues his natural-philosophical programme. Although he perhaps failed in terms of his own vision of his mature projects and aims, Descartes' interventions shifted the ground of debate in several key areas of natural philosophy, mathematics and the narrower technical sciences. Our aim is to develop an assessment of Descartes as a central figure in the Scientific Revolution of the seventeenth century, and to go some way to changing the conceptual space within which discussions of Descartes have traditionally proceeded. The essays help to establish that we must recognise, in his work, the priority of natural-philosophical considerations over the kinds of epistemological considerations that came to dominate philosophy in the era of Malebranche, Locke, and Berkeley. Indeed, the detailed accounts of the explicitly natural-philosophical way in which Descartes pursues questions of perceptual cognition, in the later essays in the volume, stands in stark contrast to the idea that the *cogito* and dualism motivate and guide his treatment of cognition.

The volume is split up into relatively discrete areas or topics, and a guide to these areas follows, but the reader will have realised by now that such divisions are not always sharp, that there are themes which underpin the whole Cartesian enterprise, and that these themes are manifested in different ways in different areas. The kinds of considerations that regulate the mechanist programme in cosmology are very different from those that regulate it in physiology, for example, although there may be unexpected and quite precise parallels, as in the very distinctive and key role of fluids in Descartes' cosmology and physiology.

Mechanics and cosmology

The essays begin with an account of the natural-philosophical tradition in which Descartes was reared and which he saw his own system as replacing. Descartes mentions Aristotelian authors by name only a few times, and the commentaries of the Coimbrans and of Franciscus Toletus are mentioned but once. Yet, as Dennis Des Chene argues, for Descartes, as for other innovators of the seventeenth century, the commentaries and the *cursus*, or textbooks, that gradually took their place in Aristotelian teaching were inescapable. The *Summa quadripartita* of Eustachius a Sancto Paulo, which draws heavily on the Coimbrans, comes up several times when Descartes contemplates using the work as an exemplar against which to set the comprehensive presentation of his natural philosophy that eventually became the *Principia*. Des Chene focuses on the immense project of the Jesuit teachers at the University of Coimbra in Portugal. He surveys the background to the writing and publication of the commentaries, examines the literary character of the texts, and explicates their natural philosophical content. He shows that the commentators, charged as they were with the defence of the faith, strove to clarify Aristotle, to reconcile Aristotelianism with the tenets of the Church, and to shear off the extravagances of their Medieval predecessors, while incorporating some of the achievements of contemporaries, often presenting what was in fact new thought under the guise of commentary, or in the *quaestiones* that accompanied the explication of Aristotle. The commentaries and *cursus* were, by and large, the historically effective Aristotle, the basis of university instruction: whether philosophers rejected, as Descartes did, the philosophy of the Schools, or, like Leibniz, mollified their leave-taking with gestures of reconciliation, or, like Honoré Fabri, continued to adhere to Aristotelian principles while contributing to the new science, for most of them the Aristotelianism of the textbooks provided a vocabulary, especially in logic and metaphysics, that was only gradually superseded. Aristotelianism, moreover, defined to some extent the problems to which philosophers addressed themselves: as is clear from the chapters in the second half of the volume, for example, the range of biological and psychological topics that Descartes took as targets for revisionary mechanistic explanation matches that of the scholastic tradition. Des Chene's essay documents the living culture of systematic natural philosophising, under dominant forms of neoscholasticism, into which Descartes and his contemporaries were inducted as adolescents.

Descartes' induction into natural philosophy had a second source, however. It is well known that when Descartes met Isaac Beeckman in Breda in 1618, they became intimate friends, with Descartes serving a sort of second natural-philosophical apprenticeship under Beeckman. They discussed several problems in mathematics and natural philosophy, approaching them with a loose amalgam of mathematics and corpuscular-mechanical theorising, which they termed 'physico-mathematics'. Ten years later, when Descartes went to Holland once again, he and Beeckman renewed their friendship and Beeckman showed Descartes his private *Journal*, in which he had noted several new ideas concerning his mechanical philosophy. Soon, however, their friendship deteriorated into open animosity. Klaas van Berkel looks at this relationship and throws new light on the reasons for its breakdown, thus explicating the first documented instance of conflict over Descartes' natural-philosophical projects. Descartes' letters to Mersenne testify to his fear that Beeckman might claim to have instructed Descartes in his mechanical philosophy. Van Berkel suggests that Descartes was alarmed by Beeckman's intention to publish his mechanical philosophy just at a time when Descartes was considering this as well. Descartes knew all too well that Beeckman and he shared some important conceptions regarding natural philosophy. Hence Beeckman's publication might destroy his claims to being the first to have discovered the right way of doing natural philosophy. Descartes' behaviour towards Beeckman and Mersenne therefore was aimed at discouraging Beeckman from publishing his booklet. In this, van Berkel shows, Descartes succeeded.

It was noted above that Descartes' particular version of the mechanical philosophy embodied his own idiosyncratic style of dynamics. In his chapter, Stephen Gaukroger explores this issue, arguing that what underlay Descartes' physical theory was not kinematics, as is generally thought, but statics and hydrostatics. He notes that Galileo, too, had used a hydrostatic model in his early account of free fall, in *De Motu*, later switching to a kinematic account of free fall in the *Two New Sciences*, where free fall in a void is taken as the core case. Descartes' strategy, according to Gaukroger, was quite different, but no less reasonable at the time, for he continued to use a statically based model. Gaukroger shows that in applying this model to cosmology, Descartes was able to explain the stability of planetary orbits, the transmission of light, and the lunar orbits in terms of the nature of the fluid separating the Sun, the planets, and their satellites. Similarly, he argues that the problematic nature of Rule 4 of Descartes' Rules of Collision can be explained if we assume that there is a static model lying behind Descartes' kinematics. He concludes that while Descartes' static and hydrostatic models produced undeniably problematic results, the success of the kinematic route to dynamics – followed by

Newton on the basis of Galileo's work – should not blind us to the strengths of the Cartesian project, as assessed in the context of his natural-philosophical agenda and the tools at hand for pursuing it.

The core of Descartes' physical theory, as he sets it out in *Le Monde* and the *Principia*, lies in the principle of the conservation of motion (or force of motion), and the three laws of nature that describe how the behaviour of bodies is governed. Peter McLaughlin explores the basic ideas behind the laws of nature, focusing on the case of collision and Descartes' problematical and much disputed conception of 'determination'. He thereby extends Gaukroger's theme of a coherent, but conceptually specific dynamics residing at the heart of Descartes' mechanical philosophy. There are two traditional interpretations of 'determination' – as actual motions or as directions of the motions – and McLaughlin shows that neither of these traditional interpretations can be correct. Rather, it is a hybrid of directionality and the absolute value of a motion. McLaughlin also deals with the nature of the force involved in impact in Cartesian physics, concluding that this somewhat obscure force needs to be clarified in terms of the two relatively better understood forces discussed by Descartes – the forces invoked in the principle of conservation of motion, and in the law of the lever. He shows that a good deal depends on what one takes the surface of collision of a body to be: once this has been clarified, the rest of Descartes' account falls into a coherent pattern.

Descartes' physics, grounded in his dynamics, may have been coherent and defendable in context, but it was almost entirely qualitative. Daniel Garber asks why this was so, and whether, as some have suggested, Descartes was fundamentally unable to see how to apply mathematics to the physical world, unlike his contemporary Galileo. Garber argues, however, that Descartes' correspondence, particularly his correspondence with Mersenne, presents a very different picture. In the 1630s, Mersenne was attempting to build upon the Galilean physics of heavy bodies, seeking to extend Galileo's treatment of machines, bodies in free fall and projectile motion to the understanding of a wide variety of phenomena. Descartes was drawn into this enterprise and his responses are very much in the spirit of Mersenne's Galilean investigations, with Descartes showing himself thoroughly adept at the Galilean programme for a physics of heavy bodies. Garber focuses on Descartes' participation in the geostatics debate and his virtual co-authorship with Mersenne of the *Cogitata Physico Mathematica* (1644). Descartes insisted, however, that his name was not to be given in print, and this raises for Garber the question why Descartes should have wanted to hide his work in mathematical physics. The explanation, Garber argues, resides in the fact that in order to do the kind of mathematical physics practised by Galileo, one had to make certain assumptions about the natural tendency bodies have to fall toward the centre of the earth with a uniform acceleration. Descartes considered these assumptions to be simply unfounded. Using these assumptions, Descartes was capable of doing physics in the Galilean style with great elegance, but for him this was only a mathematical game, not serious natural philosophy. Hence his reluctance to have his name publicly associated with it. Why, then, did Descartes not publish his own mathematical physics? Part of the reason was the complexity of the behaviour of ordinary bodies in Descartes' physics of vortices. But, Garber argues, Descartes also believed that the full mathematical account of ordinary bodies required empirical evidence that he simply did not possess. To understand the true laws that bodies obey in free fall, for example, we must know how they behave over longer periods of time as they fall through greater distances than he or anyone else had observed. Thus, on Garber's account, Descartes' response to Galileo, as well as his own explanatory agenda, arguably had more to do with matters of empirical adequacy than they did with the demands of systematisation. Indeed, as mentioned above, Descartes' concern with evidence and its management is a feature of a number of other contributions to this volume.

One of the most pressing problems concerning the metaphysical underpinnings of Descartes' natural philosophy was the nature of causation, which preoccupied many of his successors, not least Spinoza, Malebranche, and Leibniz. On the physical level, the issue structured Descartes' notion of force, while at the metaphysical level it inscribed the relation between God and his creation. Approaching the question metaphysically, the most obvious way to explicate Descartes' account was through occasionalism. Desmond Clarke looks at the treatment of causation by La Forge, one of the first Cartesians to write systematically about occasionalism in this context. For La Forge, bodies have the power to move other bodies, but he qualifies this by maintaining that they do not have a power 'from within themselves': the power is an acquired one, supplied and regulated by God. This raises the question: to what extent are bodies genuinely causally active? Clarke shows that the degree to which the Cartesian account of causation was occasionalist was a delicate and finely tuned matter, and that La Forge's attempt to reconcile the reality of the 'finite', causal powers of bodies, and their dependence on God's infinite causality was designed to maintain this delicate balance. In this way Clarke offers a particularly instructive illustration of the renegotiation of a key dimension of Cartesian natural philosophy by a later supporter, the matter having no essentially 'correct' and timeless remedy.

Compared to the metaphysically grounded presentation of his natural philosophy in the *Principia*, Descartes' *Le Monde* had treated 'nature' simply as a theoretical model built up from various elements that we can conceive of clearly. As noted above, this illustrates the variety of natural-philosophical utterance available even to an individual author pursuing the 'same' genre of natural philosophy, in this case mechanism. In his chapter, Theo Verbeek looks at the way in which Descartes' disciple Regius, who was sent *Le Monde* in 1641, develops this way of thinking about physical theory in his *Fundamenta physices* (1646). Verbeek explains the gulf between Regius' presentation of his natural philosophy and that of Descartes by the facts that Regius was writing in a largely medical context; that his highly problem-oriented method of argument owed more to Ramism than it did to Descartes; and finally, that Regius cleaved to the programme of *Le Monde*, seeing no need for the kind of metaphysical legitimation of natural philosophy that Descartes provides in the *Principia*. This illustrates the ways in which natural philosophical systematisation responded to local epistemic and institutional pressures, and how disputes could arise even amongst members of the same natural-philosophical 'school'. Regius was, as Verbeek shows, a faithful follower of Descartes, but his work led to some quite unCartesian conclusions, causing Descartes to disown both him and his theories. These issues are taken up again by Catherine Wilson in ch. 26, in the context of the mind/body question.

The idea that the ways in which Cartesianism, or any natural philosophy, was received depended to a large extent on local circumstances is further explored by Peter Harrison. He examines how English natural philosophers took up Descartes' cosmology and cosmogony, showing how it was intimately tied in with the question of sacred history, that is, the sequence of, and significance of, historical events as set out in the Bible. Harrison shows that these English controversies were not as alien to the tactics and tenor of Cartesian cosmology as might at first appear, and that Descartes' own account had already harboured an in-built sensitivity to such issues. He also demonstrates that the central issue was not whether Cartesian natural philosophy provided a parallel creation narrative. It was, rather, whether Cartesian or Aristotelian natural philosophy would shed more light on the biblical account of creation. That is, the issue was not Cartesianism versus religion, but rather which system within the field of natural-philosophical options fits better with the English reading of Genesis as history. This chapter, together with that of Peter Anstey on the development of and diversity of English responses to Descartes' cardiology (ch. 18), offers a clear, sustained picture of the response to Cartesian natural philosophy in England.

Method, optics and the role of experiment

It was suggested above that, although grand doctrines of method, such as Descartes', do not actually control the practice of the technical sciences (problem solving in traditions of scientific practice requiring field-specific tools, techniques and standards), such grand method discourses do play rhetorical roles in the presentation and negotiation of knowledge claims. It follows that both grand method theories and actual working techniques must be studied. The first two papers in this Part offer such a balanced approach.

Timothy Reiss explores Descartes' concerns with method in the context of sixteenth-century neo-Aristotelian thinking about method. He argues for a continuity, in particular, between Zabarella's attempt to reformulate the Aristotelian treatment of discovery in natural philosophy and Descartes' attempts to think through questions of method. Reconstructing the content of debates over method in the sixteenth century, Reiss shows that Descartes was aware of these disputes; that he transformed these debates and that the outcome of this transformation was his treatment of method in the *Discours*, as well as in his answers to the second set of objections to the *Meditationes*.

In contrast, Dennis Sepper uncovers what one might term the central working technique involved in Descartes' early mathematical and physico-mathematical work. In his mature mathematical work Descartes' played down the intuitive and visual aspects of geometry in favour of the 'transparency' of algebraic procedures. Sepper shows, however, that Descartes' early theory of proportions (of which his algebra is really a formalisation) was intended as a shorthand representation of the concrete, visualisable relations of geometric figures. Descartes' use of figures extended to the solution of mathematical and physical problems in early writings like the *Compendium Musicae*, the manuscripts on the proportional compasses and free fall, and in later work on the solution to quadratic equations, topics also pursued by Decyk (ch. 19) and Schouls (ch. 20). A more formal methodological rationale for this technique of 'figuration', as it might be called, was presented in the *Regulae*, where the notion that sensation proceeds by means of a kind of natural geometry is first set out, a theory which was later to be developed in the *Dioptrique*. Sepper shows that the key concept involved in Descartes' trying to capture the essential ingredients of problems in a 'figurate' way was his idea of the imagination as something that naturally operates with lines and line lengths. Ultimately the need for figuration arose for Descartes because there was for him a sense in which algebra is only potential knowledge, whilst geometry is real knowledge, its figures sharing the character of what they are about.

Sepper's analysis casts light on Gaukroger's theme of the hydrodynamic origins of Descartes' dynamics, as well as the reconstruction of Descartes' early optical work offered in John Schuster's chapter. In his *Dioptrique* of 1637 Descartes presented the law of refraction by 'deducing' it within the terms of a model in which light was represented by the motion of some curious tennis balls. Many of Descartes' contemporaries doubted the cogency of this model, and failed to grasp the theory of dynamics upon which it is based. Questions were also raised about how Descartes had obtained the 'law', if not through this dubious deduction. Schuster cuts a path of reconstruction through these controversies. Beginning with the *Dioptrique* he shows that the tennis-ball model was an adequate model for what Descartes took light to be, an instantaneously transmitted mechanical impulse, provided one understands Descartes' underlying dynamical concepts, elucidated by Gaukroger and McLaughlin in earlier chapters.

This then permits a reconstruction of how the law was discovered, or constructed, in 1626/7 by Descartes and his friend Claude Mydorge, using techniques from traditional geometrical optics. Their work involved nothing about the dynamics of light or tennis balls, raising the question of the relation between the law and Descartes' dynamical and methodological rationalisations of it. Schuster examines Descartes' earliest 'physico-mathematical' musings about light and refraction, showing that they could not have directed Descartes to the law. He argues it was only after the initial construction of the law in 1627 that Descartes literally read revised principles of the dynamics of light out of the very geometry of his key discovery diagram, forging the concepts he later used to 'deduce' the law from the dynamics of light or tennis balls. Schuster then shows how Descartes moved towards a dynamic rationale for the law, first with an ingenious balance beam analogy, followed by the tennis ball model itself. All this shows affinities to Sepper's analysis of Descartes' early figurate technique of working, while Descartes' methodological account in Rule 8 of the *Regulae* of his optical discoveries is interpreted as a cover story, obscuring the pitfalls, hesitations and incongruities involved in his long course of optical research. The final step in the reconstruction is a return to the text of the *Dioptrique* and *Météors* to show why Descartes bothered with the cumbersome tennis-ball model of light at all. The answer, Schuster argues, resided in the demands of his theory of colour, although here again there was compromise and rhetorical slight of hand, for Descartes' colour theory and his theory of light transmission did not cohere – the former required the actual translation of the light causing particles, whilst the latter denied precisely that point.

If Descartes' most important result in geometrical optics is his construction of a law of refraction, his crucial work in physical optics was in the area of the formation of colours. In his chapter, Jean-Robert Armogathe looks at Descartes' account of the formation of the rainbow, reinforcing the theme of the importance to Descartes of empirical evidence and its management, which is taken up in the final two chapters of this Part.

Guillermo Ranea shows that Descartes treated experience and experiment as something problematic that had to be regulated, thus demonstrating the existence of an earlier and continental variant of the English controversy over how one defines the 'experimental life', studied by Shapin and Schaffer. Ranea focuses on Descartes' dialogue, *La recherche de la vérité par la lumière naturelle*, in which one of the interlocutors, Poliandre, is cast as the *honnête homme*, relying on his natural faculties and not on scholastic training. In addressing himself to the *honnête homme*, Descartes is identifying an audience of practical men whom he believes he can educate to adjudicate (in his favour) in scientific controversies. Ranea therefore argues that Descartes intended his natural philosophy as something that might close controversies stirred by the endemic variability and unreliability of factual reports.

Trevor McClaughlin looks at the role of experiment in Descartes' immediate successors, focusing on the case of Jacques Rohault, one of the most distinguished Cartesian experimental natural philosophers of the second half of the seventeenth century. Given the themes of several earlier chapters, one should not be surprised that experimentalism was a legitimate development of Descartes' own project. McClaughlin outlines a number of factors that motivated and shaped Rohault's experimental programme (thereby illustrating the situational patterning of a particular variant of Cartesian natural philosophy): Rohault's close ties with craftsmen and resulting access to high quality instruments; the ever-growing threat of censorship of more metaphysically and theologically oriented approaches to Cartesianism; and the utilitarian and Baconian rhetoric of the early years of the Parisian Académie des Sciences, to which Rohault aspired, in vain, to be elected. McClaughlin succeeds in demonstrating the care taken over the management of experiment in Rohault's version of a Cartesian experimental natural philosophy, thus illustrating how 'the experimental life' was lived on the Continent, amongst committed natural-philosophical systematisers, providing a striking contrast with what Steven Shapin and Simon Schaffer have depicted – in their influential *Leviathan and the Air-Pump* (1985) – as the resolutely atheoretical and amathematical approach taken by Robert Boyle and others in England.

The natural philosophy of body and mind

The chapters in the final three Parts broadly deal with what may be termed Descartes' natural philosophy of body and mind. There is, of course, no grand metaphysical system or set of methodological prescriptions driving Descartes' work across the range of natural-philosophical domains in which he was interested. His writings on medicine, physiology, and psychology respond to a diversity of contexts and problems. To some extent his views across these areas do share a commitment to a bare 'mechanical' form of explanation, showing how natural phenomena can arise from the motions of material particles. But the range of topics and explanations canvassed in the second half of the volume demonstrate that this commitment to mechanism does not inevitably render Descartes' theories insensitive to the diversity of the phenomena in question.

Descartes' concern with what later came to be known as the life sciences focuses on cognition and physiology, and these are as integrated into a natural-philosophical programme as his work in the physical sciences. Not just that, but it is the same natural-philosophical programme: one guided by mechanism and particular conceptions of the roles of mathematics and experiment, but which is also responsive to theological, pedagogical and other considerations, and which is located in an often fierce combat among competing natural philosophies in which particular issues come to occupy centre-stage for reasons which may be quite independent of the trajectory of Descartes' own research or that of his followers; he (or his followers) has however to take them on to establish the credentials of his own programme. This is true of his work in mathematical and physical enquiry, and it is no less true of his work in the life sciences, which were in many respects an even more contentious area.

Under the rubric 'life sciences' are included some areas which are to us straightforwardly biological, such as general physiology, cardiology, and embryology. But they also include a number of domains which blur our own disciplinary boundaries, such as imagination, perception and the senses, memory, the passions, psychosomatic medicine, and the psychology of meditation. As the essays show, Descartes employed a variety of methods for addressing these topics. Two common misconceptions are clearly rejected: on the one hand, Descartes was no less concerned with empirical evidence in physiology than in optics, and he undertook sequences of anatomical and physiological experiments, for example in embryology and on the circulation of the blood. On the other hand, his own claims to be devising entirely new theoretical frameworks should not blind us to his reliance on a range of (often unnamed) sources in Renaissance medical writings.

Physiology

It has long seemed obvious that Descartes' defence of an incorporeal and immortal soul or mind was coupled with a set of unfortunate concomitant views about nature, the body, and the physical world. Even the most complex natural operations are to be reduced to mere clockwork; second, the messy, pulsing, decaying and regenerating processes of the biological realm are, in the infamous 'beast-machine' doctrine, to be reduced to unconscious and unfeeling automatism; and, finally, the human body is either to be loathed as a hindrance to our true and distant goal, or at best to be mechanically maintained as the soul's temporary vehicle. Along with the division of mind from body, the realm of meaning is, according to this mythical Cartesianism, to be divorced entirely from the science and the realm of causality.

The genuine force of Descartes' mechanisation of physiology lies in his rejection, examined in many of these papers, of vital and animal souls. In Christian-Aristotelian orthodoxy, these intrinsically organic souls, distinct from the rational soul, were meant to explain the animation of biological matter and the various physiological processes. Descartes was concerned, like his friend Marin Mersenne, with eliminating the possibility, implicit in certain naturalistic Renaissance medical writers, that the self-organising powers of specific biological matter might extend to reason, since this would threaten beliefs in immortality. Attacking the indiscriminate attribution of intention and intrinsic purpose to organic parts, Descartes insisted that organic corpuscles have no more powers of deliberation or reasoning than do any other parts of the realm of extended matter. Thus far is the mainstream account vindicated. There is no doubt that Descartes was committed to the ultimate inertness of matter, and to the idea that ultimately order and complexity must derive from the external activity of the Creator. But there is considerable doubt that this basic commitment to inert matter entails that there is no genuine development and self-organisation in nature at all, or that natural philosophy should not be a legitimate path of investigation into its changing processes.

So while it is true that even the most complex natural processes are to be reduced to mechanical operations, this does not mean that they are all simple clockwork. As several of these studies stress, we can be easily misled by our images of clinically regular wheels and cogs into thinking that Descartes is simply eliminating the biological in advance. In fact, many seventeenth-century conceptions of the machine did not render complexity incompatible with mechanism, and the idea that organic bodies are machines did not entail that they are hard, rigid, or preprogrammed, as opposed to fleshy, flexible, and adaptive. As with Descartes' fluid-based physics and cosmology, there is a sense in which complexity is built into the physiological system once it has been set in motion.

Although he never took a degree in medicine, Descartes had an extensive grasp of anatomy and physiology. William Harvey and other physiologists discussed his ideas on the nature of blood and the movement of the heart and he was consulted by physicians on medical problems. Annie Bitbol-Hespériès looks at Descartes' work on physiology. She takes as a test case his differences with Harvey over cardiology, and his account of the union of mind and body, showing how Descartes eliminates both the devotional wonder at the body that characterised teleological traditions, and also a series of old 'cosmobiological' links between body and cosmos, such as the idea that the action of the heart can be modelled on the sun.

Stephen Gaukroger's chapter begins by looking at more general questions about the aims of a mechanist physiology. Stressing the importance of Descartes' theory of matter in his account of physiology, he shows how this account is in stark opposition to more traditional attempts to explain differences in physiological function, either in terms of different kinds of matter (the four elements) or in terms of the Aristotelian vital, animal, and rational souls that animate matter at different levels. The bulk of the chapter is then devoted to discovering what resources are available within the framework within which Descartes chooses to work, and it focuses on two such resources. The first is his elimination of a goal-directedness from physiological processes, the clearest case of this being in his embryology. The second is his attempt to deal mechanistically with processes that involve receptive capacities, something manifest in his treatment of perceptual cognition.

In pursuing his mechanistic physiological programme, Descartes invokes his doctrine of *'bêtes-machines'* (animal machines). Katherine Morris examines just what is involved in this notoriously problematic and contentious doctrine. She argues, first, against the idea that animals are unconscious, that they can neither think nor feel: on the contrary, she points out that it follows from Descartes' doctrine that they can feel. Against the neo-Aristotelians, who ascribed sensitive souls to animals, Descartes' view is that sentience can be explained mechanically. The post-Montaignean argument, which held that animals could think, and hence must have a rational soul, was something that Descartes could not refute in such a clear-cut way. Possession or non-possession of a rational soul was an essential matter, so he could not demonstrate empirically that animals lacked rational souls. Nevertheless, he did argue that it was 'morally certain' that they lacked rational souls. Morris manages to tease out the intrinsically moral force of the human soul in Descartes' natural philosophy, as the bearer of responsibility and free agency. This nuanced understanding of the role of the soul in Descartes' system makes it difficult to separate Descartes' account of mind from his metaphysics, theology, physiology, and ethics.

Peter Anstey, arguing that the details of Descartes' account of the circulation of the blood have not always been properly understood, examines the case of Cartesian cardiology. The issue is not merely one of physiology, however, for basic questions of natural philosophy were tied in with Cartesian physiology, and its reception was closely bound up with natural-philosophical issues. Anstey shows this by using the reaction in England to Descartes' cardiology as a test case to throw light on the connections between questions of physiology and questions of natural philosophy. Some responses, like that of Digby, were purely natural-philosophical whereas others, like that of Lower, were purely physiological, yet the response in England, unlike that in continental Europe, was uniformly negative. As Anstey shows, despite the fact that there was no comprehensive evidence against Descartes' idea that the movement of the heart is caused by the ebullition of the blood until Lower's work on the colouration of the blood in the late 1660s, and despite deep divergences in natural philosophies in England, ranging from Harvey's vitalism to Boyle's mechanism, rejection of Cartesian cardiology transcended all party disputes.

Imagination and representation

In a number of the chapters on imagination and thought, Descartes' accounts of perception, imagination, and memory are described in terms of the coding, transmission, and reconstruction of information. The history of cognitive science, often seen as the unmasking of one or other of Descartes' errors, may in fact provide some resources for subtler readings of his views. It is not by any means that all the contributors are sympathetic to the general project of cognitive science: indeed, some explicitly deny the utility of the information-processing interpretation. But even when they look back to quite different alternatives, describing Descartes' reliance on earlier traditions of faculty psychology, or perspectival art, they are seeking more naturalistic readings of his project than the traditional focus on dualism alone would allow.

While we see perception, dreaming, memory, and imagination as specifically cognitive functions, for Descartes they were, in one legitimate sense, life functions, on a par with respiration and nutrition. In this sense, beasts do have genuine memory and perception, and many such functions in humans operate for the most part without the intervention of the soul. Pursuit of Descartes' extensive accounts of the nature of these capacities sanctions attention to the details of psycho-physiological processes, and locates his work in a longer history from Aristotelian theories of the internal senses to the nineteenth-century psycho-physics described by Gary Hatfield, and beyond. Obviously it is not enough simply to announce that computational neuroscience, for instance, is now modernising Descartes' vision of reflex action in neural nets: but the hope is that sensitivity to obstacles and problems in our own attempts to naturalise cognitive capacities may help to refresh contextual historical readings of the philosophy of mind.

As a result, the place of imagination in Descartes is thoroughly reevaluated. Rather than an unfortunately particularising capacity which distracts us from the true business of abstract thought, imagining in its various forms appears (especially in the chapters by Sepper, Decyk, and Schouls) as an essential bridge between theory and practice. In turn, the role of memory is reconceived: instead of being the general and untrustworthy means by which the results of intellectual intuitions have to be stored in the mind, remembering appears (especially in the papers by Fóti and Sutton) as the focus of Descartes' attempts to make us more aware of the effects of our own specific and embodied history. Closer attention to the detailed operations of the nervous system, and in particular to its ties with the circulatory and digestive systems, reveals surprising complexity, activity, and interconnectivity in the human body according to Descartes. Finally, contexts appear for the pineal gland and the 'animal spirits' beyond the notorious absurdity of linking natural and supernatural realms: even within the animal economy, organic automata (and humans when their minds are elsewhere) can form genuine representations of the world, patterns or traces, which retain the effects of experience and which ground adaptive responses over time.

These representations are neither ontologically ambiguous sense-data, nor simple reflections or copies of objects. Many of the contributors quote passages in which Descartes rejects the idea that representation operates by resemblance. The patterns traced by neural fluids on the surface of the pineal gland are not pictures of things, to be viewed or interpreted by the separate soul. At least this is clearly the shape of the theory for which

Descartes hoped, and it is only after acknowledging the scope of this ambitious programme for the mechanistic explanation of various specific perceptual capacities that Celia Wolf-Devine, for instance, is able to convict him of failing successfully to discharge the 'homunculus'. In the symposium on perceptual cognition, the differing views taken by Peter Slezak and John Yolton, for example, on whether or not Descartes was seeking a primarily causal/mechanistic theory, directly reflect their respective positions on current issues in philosophy of mind.

According to these reinterpretations of Descartes, the mind is not seeking simply to reflect or mirror a static world. This is to question a persuasive narrative synthesised and entrenched by Richard Rorty, who attributes the divorce of questions of practical, moral, and political importance from philosophy in part to the seventeenth-century invention of a 'veil of ideas', which seems to cut us off from the natural and cultural environment. A number of the essays in this volume reject the idea that Descartes removed perceptual processes so decisively from nature. He did indeed deny that we are unproblematically aware of the true nature of our world, and did insist on the gap between appearance and reality to which his corpuscular mechanism committed him. But the fact that processes of selection, distortion, reconstruction, and enrichment operate on perceptual data is precisely a spur to understand both the general 'natural geometry' of perceptual cognition, and the specific idiosyncrasies of experience which drive different individual responses. We can recover information about real objects without it simply being impressed or copied, just as we can retain and reconstruct past episodes and events without the past events having to be permanently stored at single inner locations.

In her chapter, Betsy Decyk looks at the connections between perspectival painting and Descartes' natural philosophy. The perspectival tradition had, not surprisingly, elevated the standing of geometry, although Alberti had argued that a knowledge of geometry is even more important than a thorough grounding in the liberal arts for the painter. Both the writers on perspective and Descartes thought of our understanding of nature in terms of an ability to geometrise it. Moreover, both thought in terms of a two-dimensional grid imposed on a three-dimensional scene: in Descartes' case this grid is psycho-physiological, and it is a distinctive operation of the imagination, whereas in the perspectivists' case it is a physico-geometrical device that defines mathematical relations between objects in the picture. Decyk stresses the idea of the grid as an overlay in both cases, and draws attention to Descartes' descriptions of the imagination as providing a mathematical overlay on corporeal objects. Moreover, both the perspectivists and Descartes are intrigued by the flexibility or transformability of the optical/perceptual image.

Peter Schouls' chapter continues the investigation of Descartes' account of the imagination as a crucial source of hypotheses. He argues that just as there is a corporeal and an intellectual memory in Descartes, so too is there a corporeal and an intellectual imagination, and it is the latter that plays the more important role. Indeed, it ultimately underpins the relations between poetry, philosophy, art, and science. Schouls concentrates on the case of intellectual imagination in algebra and in geometry, where the diagrams it helps us to produce can mediate between pure thought and its practical applications. In turn, the neurophysiology by which the corporeal imagination is to be understood explains how what is first merely imaginatively possible can be linked with the actual in the physical world.

The problem of visual spatial perception presents serious difficulties for Descartes' project of finding a wholly mechanistic account of vision. Celia Wolf-Devine argues that the core mechanism of vision comes close to providing what he wants, a kind of mechanised Aristotelianism that conveys the figure of an object (rather than its 'form') to the soul at the pineal gland. But it does not account for how the defects of that image (such as two-dimensionality, inversion, perspective distortions) are corrected for, and Descartes does not succeed in providing any mechanistic explanation that he finds completely satisfactory, especially for size and shape perception. He is therefore driven to hypothesise an increasing role for judgements by the mind. But this leads to problems. If the mind is to correct for defects in the retinal image, it must have some access to that image – something very hard to explain on Descartes' premisses. Furthermore, the problem of animals' visual spatial perception becomes insoluble if judgement or reasoning is necessary to account for the perception of distance, size, and shape by sight. And if their perceptual abilities can be explained without reference to either conscious sensations or judgements, why not do the same for human visual spatial perception?

One of the most important stimuli for rethinking Descartes' account of perceptual cognition in recent years has been the work of John Yolton, who has suggested that Descartes' theory of perception is not a form of indirect or representative realism, but a form of direct realism. Yolton's influential reading drew attention to Descartes' discussion of perceptual cognition as the grasp of natural signs in the first chapter of *Le Monde*, and argued that, like his follower Arnauld, Descartes saw the relation between brain traces and the mind as significatory or cognitive, rather than simply causal. In ch. 22, four commentators address Descartes' view of perceptual cognition, and Yolton's interpretations of it. David Behan puts the issue in the context of sophisticated late scholastic discussions of signs. While supporting the view that, for Descartes, brain motions are signs to the mind which lead it to produce a sensation, he queries Yolton's direct realist interpretation of Descartes, and seeks to clarify Yolton's distinction between representation and signification. Peter Slezak agrees with Yolton that historical debates may be relevant to foundational issues in modern philosophy of mind, such as the nature of representation, but argues that the passages cited by Yolton in support of a non-mechanistic account of perception are in fact compatible with a purely causal view. The centrality of implicitly causal language for describing the relation between brain motions and sensations is also defended by Celia Wolf-Devine. She goes on to reject a key claim of Yolton's 'reverse-sign' doctrine, the notion that physical motions in the brain signify not objects in the world, but sensations. Finally, Yasuhiko Tomida examines the relation between the perceptual and the corpuscularian theory of matter shared by Descartes, Locke and others, questioning Yolton's claim that Descartes and other early modern philosophers were concerned to set out a form of direct realism, and not a view of perception in which ideas stood proxy for the objects perceived. In his response, John Yolton replies to the various views with concessions on some points of his interpretation, accepting for example that the brain motions signify objects rather than ideas, but with a vigorous defence of others, such as Descartes' realism.

Mind and body, thought and sensation

The various approaches to Descartes' dualism in this volume offer quite different perspectives on the vexed questions of the relation between mind and body, and the nature of thought and sensation, going beyond the usual uncomprehending complaints about Descartes' unlikely solutions to the problem of causal interaction between thinking substance and the pineal gland. The re-evaluations do not swing to the opposing pole by following La Mettrie's claim that Descartes was a closet materialist. Instead, in one way or another exploring Descartes' insistence on the theoretical and practical importance of the union of mind and body, they agree in stressing his rejection of the Platonic or angelist version of dualism in which the soul is merely lodged in the body as a pilot in a ship. On the other hand, as we have seen, the revisionary perspectives on the natural philosophy of the body in this volume challenge the claims about Descartes' evisceration and disenchantment of nature in a number of ways.

Hence, while it is true that animals are automata and have, for Descartes, no rational souls (they are, in Katherine Morris' term, 'conscienceless'), this does not mean that they lack sentience and all awareness: although as John Wright points out, the Cartesian natural philosopher Claude Perrault did question Descartes on this doctrine and tried to reintroduce the soul to explain vital functions and sentience. In Descartes' view, as several contributions stress, these automata specifically are organic, in some sense self-moving machines. Descartes did rule out the possibility of a science of (rational) mind, but he allowed and encouraged the investigation, within natural philosophy, of many capacities shared by humans and beasts. There can, then, be sciences of motor control, vision, sentience, imagination, memory, and dreaming.

Similarly, while it is true that the operations of the human body, including the brain, are no longer (since the Fall) within the voluntary control of the soul, and thus that the moral life demands some vigilance against the unanalysed effects of bodily habits, this does not mean that the soul is inevitably and irretrievably hostile to the body with which it is united. In medicine as in morality, Descartes hints at theoretical and practical programmes for the careful mapping, exploration, and only ultimately exploitation of a range of truly psychosomatic phenomena. Although there are some differences of emphasis among the chapters that touch upon this issue, nowhere here is there much support for the picture of Descartes as evil metaphysical magus, seeking to make us masters and possessors even of our own bodies, anticipating the technologising impulse of later relentless modernisers. Cartesian physiology and psychology are thus here revealed not as symptomatic of the 'death of nature', part of the objectification of a barren cosmos, but rather, in Karl Rothschuh's words, as 'representative of the baroque', with Descartes exemplifying 'a dynamic interpretation of nature'.

Véronique Fóti looks at Descartes' distinction between two kinds of memory. The first, which is discussed extensively in the *Regulae*, is corporeal, and is discussed in psychophysiological terms. The second kind of memory, intellectual memory, is more elusive, and discussion of it is confined to Descartes' correspondence from 1640 to 1648. Fóti argues that some light can be thrown on the nature of intellectual memory by considering the *Meditationes*, where Descartes argues that, in the course of a proof, although he may remember having proved something, if he has 'turned his mind elsewhere', that is, if there is a break in continuity in memory, he cannot remain assured of its proof. It is not immediately clear just what the problem is here – misremembering and difficulties with the faculty of memory as such seem to be ruled out – and Fóti uses the problem to try to tease out just how Descartes may have conceived of intellectual memory.

In his chapter, Gordon Baker discusses the relation between sensation and thought by focusing on Descartes' claim that the senses are unreliable witnesses. When Descartes makes this claim, Baker suggests, he is presupposing that sense perceptions can only be contradicted by other sense perceptions, and each sense report can be treated as a separate piece of testimony, that is, as the report of a fresh witness, whose degree of reliability is not known. It is in this context that Descartes' warning that we have been misled by sense-perception in the past should be read: in particular, he is not, *per impossibile*, suggesting that we can do without sense perception. However, on the face of it this interpretation conflicts with the way in which Descartes leads up to the point, with some of the things he apparently concludes from it, and with the fact that he occasionally seems to suggest that the senses and the pure intellect can conflict. To yield a consistent interpretation, Baker argues, we need to go back and discover the purpose behind Descartes' analogy between sensation and witnesses. Two considerations are important here. First, when Descartes says that what he has accepted as most true up to now has been acquired 'through the senses', the relevant contrast classes are the two other cognitive faculties – the imagination and the intellect. Second, 'most true' means something like 'having the highest degree of certainty'. And when he tells us that the senses have occasionally deceived him, and that therefore we should not trust them completely, he is saying that, in cases of perceived conflict, although he has shown a preference for the testimony of the senses, we should not automatically resolve any conflict between the senses and the intellect in favour of the senses. Whereas modern readers have found this line of reasoning opaque or speculative, educated seventeenth-century readers would have found it perfectly familiar, and the difference arises, Baker argues, because of a very different understanding of the provenance of logic in the seventeenth century, which includes what Baker calls a 'logic of testimony'. Descartes' overall aim is to establish the narrow jurisdiction of the senses, and the comprehensive scope of the intellect, whose principal power is *conscientia*.

The radical dualism of the *Meditationes* has generally been characterised in terms of its putting all accessible mental states on a par and its treatment of sensory qualities as being mental. Gary Hatfield draws attention to two other aspects of Descartes' account of the mind. The first is his stress on the pure intellect. A fundamental aim of the *Meditationes*, an aim on which its metaphysical arguments depend, is to make one aware, perhaps for the first time, of one's own faculty of pure intellect. Descartes' project is to alter the reader's Aristotelian beliefs about the faculties of the mind while at the same time drawing one into using the newly recognised faculty to perceive the first truths of metaphysics. By his own lights at least, Descartes' achievements in the *Meditationes* must stand or fall with the correctness of his anti-Aristotelian understanding of the power of pure intellect. The second theme concerns Descartes' naturalism about the mind. It has been common to see Descartes, in virtue of his substance dualism, as having placed the mind 'outside nature'. He made the world safe for mechanistic physics by deanimating the 'physical' world, that is, the world of particles in motion, and collecting all mental phenomena in the soul as a separate substance. But, as Hatfield argues, Descartes included the mind as part of nature, and despite his dualism he continued an established line of thought according to which the operation of the senses is open to empirical investigation; indeed, in virtue of his dualism, he indicated a new line of thought leading to the search for specifically psycho-physical laws, that is, laws linking non-mental bodily states to states of mind. The question is whether the combination of these two themes, the idea that the pure intellect provides the normative foundation of his metaphysics, and his view that the intellect is in some sense natural, is effectively an appeal to psychologism. Hatfield argues that the question is not so straightforward, and in particular that the relations between the terms 'mind', 'nature', and 'psychology' in early modern thought is more complex than it has generally appeared.

Catherine Wilson explores the hermeneutics of Descartes' account of the mind and the body. Experience and cognition are sometimes described as if they were purely corporeal functions, and at other times experience and thinking are described as if they were independent of the body altogether. Wilson argues that we get ourselves into unnecessary difficulties if we treat this as an either/or situation; rather, there are degrees of belief and Descartes' claims have to be located within a continuum of degrees of beliefs. This raises the question of the hermeneutics of belief, and several hermeneutical devices can be identified in seventeenth-century writing: raising theses as possibilities, even if one goes through the motions of refuting them, means that theses that would otherwise not be taken seriously have to be considered on their merits; and giving intentionally unconvincing arguments for a conclusion while omitting more plausible arguments for it are a way of undermining the conclusion. Descartes' critic Voetius accuses him on these counts, and specifically charges that he gives poor arguments for the mind/body distinction so as to undermine it while appearing to support it. And to complicate matters of interpretation, there is a shift in Descartes' thinking away from stressing the similarity between human and animal faculties in *L'Homme* to stressing their differences in the *Meditationes*. Following through the disputes with Regius, Wilson highlights the highly contextual nature of a number of the claims about the mind/body relation, and points to a fundamental ambiguity in Descartes' position.

In his chapter, John Wright explores the response to Descartes' theory of soul in the work of the late seventeenth-century natural philosopher Claude Perrault. Wright describes Perrault as taking issue with a number of specific themes in Descartes and Malebranche, seeing the union of soul and body as fundamentally voluntary and under the rational control of the individual soul. Complaining that Descartes gives corporeal explanations for many functions of the soul (an interpretation which, however unusual among twentieth-century historians, was common in the early modern period), Perrault refers life functions as well as cognitive functions to the individual will of the organism, rather than to nature or to God.

John Sutton argues that Cartesian physiology is modelled on fluid dynamics: bodily processes, including the whirl of animal spirits across the brain's folds, are context-dependent and causally holistic. The innards are reciprocally joined to the cosmos and culture: bodies are but temporary pockets of stability. Corporeal memory and imagination mark brain pores with specific histories; the permeable bodies of animal automata bear traces of particular experience. Because long-term memory involves this plasticity, compound creatures like humans, who think as well as dream, can use the mechanisms of association for moral purposes. The extended autopersuasion that Descartes recommends to Elizabeth and in the *Passions* is the deliberate alteration of the physiology of passion and association by effort and habit. Virtue is the application of intellect and will to extend control over bodily and associative responses normally beyond conscious reach. So expertise on the self involves a slow immersion in embodiment, and psychological work on one's own history and body. Analysis of Descartes' notions of disposition, habit, and temperament shows Cartesian ethics to be a set of provisional maxims, applicable differently in each individual, for applying intelligence to the reflexes, and recolonising the body.

Dennis Des Chene begins by noting that, although Descartes' natural philosophy has as one of its chief aims the preservation of health, he seems to have no normative conception of well-being. Such normative conceptions are difficult to capture in a natural philosophy which does not allow notions of ends, but Descartes did have two ways of approaching the question. The first was via a biomechanics, which treats the body in isolation from anything else, as a piece of material extension, so that any ends it has are external to it. Although this is the way in which most commentators have conceived of Descartes' approach to medicine, Des Chene argues that it is in fact via the completely different route of psychosomatics that Descartes approaches these questions. The difference is that, on the psychosomatic conception, the object of medicine is the union of mind and body, something which has ends that are internal to this union. Nevertheless, there are both biomechanical and psychosomatic trajectories in Descartes' thought and Des Chene brings these out by looking at the views of the next generation of Cartesians on the question of health, showing how Andreae adopts a psychosomatic model, Barbeck a biomechanical one, with Clauberg somewhere in the middle. As to the evolution of Descartes' agendas in this area, there is a clear difference of emphasis between Des Chene and Wilson: Des Chene sees a far-reaching transition, partly under the influence of Princess Elizabeth, from the pure early 'biomechanical' medicine to the more contextual and individualised psychosomatic medicine by the time of *Les Passions de l'Âme*; while Catherine Wilson rejects the idea that any crisis turned Descartes from an austere metaphysics to a richer sense of embodied and passionate life. As we have seen, she argues instead that the defence of dualism was a temporary and context-dependent interruption to a continuous and consistent interest in the psychophysiology of the mind/body union.

Descartes' account of cognition is in some respects more alien than it first appears, and in other respects more familiar than it first appears. His account of knowledge, as set out in the *Meditationes*, seems unproblematically familiar, however archaic the reliance on God might seem. But this reading is possible only on condition that we minimise the element of 'meditation' in the *Meditationes*, that we treat the meditative element as something we can abstract from the text. Dennis Sepper argues that, in doing this, we may be missing something very crucial in the *Meditationes*. The term 'meditation', although traditionally associated with a religious form of reflection (in Augustine and Ignatius, for example) had also traditionally had a specific philosophical significance, a significance it continued to have in Descartes' time. It was basically a kind of thought (*cogitatio*) standing somewhere between cogitation and contemplation: cogitation begins with sensory and memorative images of things which touch the mind; consideration of these cogitations with the aim of discovery constitutes meditation; and the recognition of something unifying or pervading the manifold is contemplation. Descartes' early biographer Baillet tells us that he called the operations of the imagination 'meditation' and those of the understanding 'contemplation'. As Sepper points out, there is nothing specifically devotional in this use of the term 'meditation': its orientation is psychological and indeed the tripartite cogitation/meditation/contemplation structure is part of a larger network evident in the traditional psycho-physiological theory of the internal senses in which Descartes was steeped. The early *Regulae* exhibit this meditational quality, the cognitive value of the imagination playing a key role, but Sepper argues that, despite a restriction of the direct cognitive value of the imagination in the later works, it is also to be found in the *Meditationes*, where the distinctive meditational process of going back over material, resuming previous considerations, taking up earlier considerations that have been put aside or left incomplete, is followed. What is involved is a distinctive – 'meditational' – way of thinking through problems that has disappeared from our culture but which informs Descartes' approach.

Part I

Mechanics and cosmology

1 Descartes and the natural philosophy of the Coimbra commentaries

Dennis Des Chene

Descartes mentions the commentaries of the Coimbrans only twice in his correspondence.[1] In 1640, anticipating objections by the Jesuits to the *Meditationes,* and having some desire 'to re-read a bit of their Philosophy', he asks Mersenne to send him the names of the authors 'whom they follow most closely'. Wondering whether anything new has appeared in the last twenty years, Descartes adds that he recalls 'only the Coimbrans, Toletus, and Rubius'; he also remembers, but not by name, 'a Chartreuse or Feuillant' who wrote an *abrégé* of 'the whole School Philosophy'.[2] That author turned out to be Eustachius a Sancto Paulo, and it was to Eustachius' *Summa quadripartita,* which is indeed a greatly condensed compilation of other philosophers' works, that he eventually turned; he still wished, however, that the Coimbrans had written something as brief, since he would have preferred to 'deal with the great Society itself, rather than with a particular person'.[3] Descartes briefly envisaged the uncharacteristic project of a commentary on the School Philosophy – a reprint of the *Summa,* to which Descartes' own *disputationes* would be attached.[4] He gave that up after a year or so.[5] The *Principia philosophiae,* which by then he had begun, contains no Aristotelian arguments; it mentions no philosopher of the Schools by name. Eustachius, Coimbra, Abra de Raconis, the tags remembered from his days *sous la férule* at La Flèche, the fruits of his recent attempts to arm himself against the 'grande Société': all are absorbed into a mass designated by the term 'Philosophers', from which only Aristotle himself emerges to be named. In that distinction one may already divine the subsequent divergence of Aristotle's fortunes from those of almost all his commentators. His works, after a temporary eclipse, have regained their central place in the canon; all but a few of the commentators have vanished into the archive of the unread.

The impression one gets, from not only Descartes but almost all the *novatores,* that Aristotelianism had arrived at its twilight hour, is not entirely mistaken. Among the hundreds of commentaries and *cursus* published from 1550 to 1650, some are routine, or dogmatic, in the way that textbooks can be in any age; and all of them, routine or not, are but rarely cited, except among themselves, after 1700 or so. But the best of them represent the last efflorescence of a philosophical movement that had dominated the universities of Europe for four centuries. Among the most widely disseminated were those of Jesuit authors responding to the post-Tridentine call for a renewal of Catholic teaching in the face of schism and heresy. One aspect of this was to make Aristotle more accessible and to stabilise the interpretation of his texts, scraping away layers of controversy that had accumulated since Albert and Thomas. Like philosophy itself – the two were hard to distinguish then – the Aristotelian *corpus* was an ambiguous instrument: in the battle against nonbelievers, it helped recruit to the cause of the Church the power of reason, which if effective would remove the need for powers less subtle. But it was also much in need of discipline, to chasten any claim to equal authority with faith and tradition.

In this essay, I focus on the ambitious project of the Jesuit teachers at Coimbra: a set of up-to-date commentaries extending to all the texts regularly included in the philosophy curriculum. In their period the commentaries were rivalled only by the somewhat later *Disputationes* originating from the Carmelite Colegio de San Cirilo at Alcalá, collectively known as the Complutenses. The impetus behind them came from Petrus Fonseca, author of a massive *Metaphysics* commentary. Fonseca's contribution was a commentary on Aristotle's logical works, the *In universam dialecticam;* other authors, principally Emmanuel de Goes, wrote commentaries on the physical works, *De anima,* the *Parva naturalia* and the *Ethics*. The series, which began publication in 1592, was widely reprinted; the last editions were published around 1630. The *Summa* of Eustachius, which draws upon them even to the point of verbatim repetition, was reprinted as late as 1647.

I will treat two standard *quaestiones* to illustrate the methods and conclusions to be found in the Coimbra commentaries, contrasting them with the same *quaestiones* in other Jesuit authors, especially Franciscus Toletus and Franciscus Suárez. Toletus' commentaries, on the *Organum,* the *Physics,* the *De generatione et corruptione,* and the *De anima,* were first published in 1572. Suárez, who spent his last two decades at Coimbra, incorporated what were likely to have been notes on *Physics* and *De generatione et corruptione* courses into his *Disputationes metaphysicae,* first published in 1597.[6] Descartes mentions Toletus just once, in the passage cited above; Suárez is mentioned only in the Fourth Replies,[7] but Descartes is likely to have known something of the *Disputationes*. As will become clear, my interest is not in specific parallels or anti-parallels, but in comparing systems of thought.

Matter, act, and God

Prime matter, one of the two components of corporeal substance in Aristotelian physics, has long been a puzzle even to sympathetic readers. Even if Aristotle's own conception were clear, the conceptions of sixteenth-century Aristotelians, resting as they do on a lengthy and complex history of interpretations, would require further investigation. One of many reasons for this is that the most straightforward reading of Aristotle's own concept – that matter is a kind of indeterminate stuff, standing to all natural forms as sculptor's clay to the forms of statues – will not work for most Aristotelians, even if it works for Aristotle. In particular, the Thomist interpretation, which will figure prominently here, of matter as pure *potentia* would seem to preclude the straightforward reading.

Physics commentaries and Aristotelian textbooks typically devote several questions in Book 1 to prime matter, which together with form and privation, is one of the three *archai* or principles of corporeal substance. Aristotle argues that through any physical change something must persist. In substantial change, like the transmutation of elements or the death of a human being, not only the accidents of a substance are altered but the substance itself changes in kind. Even then something persists, since otherwise we would have annihilation and creation, not change. What exactly remains through substantial change was controversial. But there was general agreement that prime matter, at least, remains: what changes is the substantial form. This, the most 'physical' of the many arguments for the existence of prime matter, leads to the conception of corporeal substance, henceforth distinguished as *complete,* as the union of two *incomplete* substances, namely, substantial form and prime matter.

Supposing the existence of prime matter to be proved, the task remains of defining it. One could ask, for example, whether prime matter is *per se* divisible, or whether it can have quantity or any other accidents except by virtue of form. My primary concern here is the *mode of existence* of prime matter. Specifically: is prime matter, as Thomas and the Thomists argued, *pura potentia,* pure potentiality, or does it have an *actus* or actuality of its own?

There is no doubt that matter exists when joined with form in the complete composite substance. 'Form gives being', as the slogan has it: the potentiality of matter, indifferently directed towards any and all corporeal forms, is actualised in the composite. There was general agreement that the actuality of matter in the composite included its being specified by form as a certain kind of material thing; the question was whether it also included the very existence of matter. In other words, does matter, considered in itself and apart from form, have an *actus* or actuality? (Since we are talking about a substance, rather than a power, the term *actus* may be taken to be equivalent, except in connotation, to the term *existence.*) The answer of Toletus and Suárez is a qualified *yes;* the Coimbrans' answer is *no.* But we will see that the difference is not so great as it first appears. For one thing, Toletus and the Coimbrans agree in rejecting the answer given by two 'noble philosophers of the Aristotelian family', to quote the Coimbrans, Duns Scotus and Henry of Ghent. The two noble philosophers' answer was to attribute to matter itself an *actus entitativum* – the Coimbrans gloss the term as 'the thing existing in act'.[8] Suárez, for his part, thinks that the Coimbrans, whatever they say, agree with Scotus in substance, and disagree only with the Scotist way of expressing the view.

Toletus

In Toletus' commentary, the question of the mode of existence, or *entitas,* of matter is raised in answering an objection to the claim that matter is substance: namely, that if matter is *pura potentia,* then since substance is *actus,* matter is not substance. Toletus begins with a series of distinctions among *actus.* The only one pertinent here is between *actus perfectus,* which is that of a complete substance, and *actus imperfectus,* that of each of the components. With that distinction in hand, Toletus concludes first, that matter is not '*in potentia* to every sort of substantial *actus* whatsoever' because if it were it would be nothing at all. But since it is not a complete substance, it does not have an *actus perfectus,* but only an *actus imperfectus,* which, since we are talking about prime matter and not, say, the proximate matter of the human being, can take on any *actus perfectus.* That is a roundabout way of saying it can take on any form. In that sense matter is indeed *pura potentia,* like the sculptor's clay, and like the clay also, it has an *actus* or existence of its own. The import of that claim becomes clear when Toletus briefly argues that, contrary to the opinion of Thomas, matter can, by the absolute power of God, exist without form, precisely because it has not only a distinct essence but a distinct existence.

Coimbra

On the face of it, the Coimbrans disagree. Matter, in their view, has no *actus* or existence of its own; it is *pura potentia,* not just with respect to form but absolutely. But the Coimbrans also agree with Toletus and Suárez – thus departing from Thomas – that matter can exist without form. That, together with their inclusion of matter in the nature of a corporeal substance, makes their position not quite as clear cut as it would seem at first; the combination of views is what leads Suárez to regard their denial of actuality to matter as largely a matter of words.

Their primary argument on behalf of the denial is this: 'if matter were not *pura potentia,* it would either be *actus* alone, or something made up of *actus* and *potentia;* but neither alternative can be maintained', and so matter is *pura potentia.* Taking up the first horn of the dilemma, they argue that every *actus* is either that of form as part of a complete substance or a self-subsistent *actus,* like that of God and the angels. 'Self-subsistent' in this context simply means 'subsistent apart from matter'. It is obvious enough that matter cannot have such an *actus.* As for the other horn of the dilemma, if matter consisted in a composite of *actus* and *potentia,* we would have a matter which was itself composed of two other things, and thus a regress.

Concerning Scotus' position, the Coimbrans write that 'this [. . .] opinion and way of speaking does not satisfy [us]'.[9] Aristotle knows nothing of *actus entitativus*. Glossing that term as 'the thing existing *in actu*', they argue that 'matter, although it acquires an *actus* of existence, and indeed its own [*actus*], is still not formally the same in every way as [its *actus*], if indeed the existence of each thing is distinct by nature from its essence' (a point they prove elsewhere). The concession here of a proper *actus* to matter will not go unnoticed by Suárez.

The Coimbrans concede an *actus* proper to matter in two other contexts. The first occurs in answering an objection to the claim that 'matter is part of the essence of a natural composite [substance]'.[10] With Durandus, one might ask: how can matter be part of the essence of anything if it is *pura potentia*? Matter so defined is incapable of distinguishing one thing from another, or of having any sort of unity. To that the Coimbrans reply: 'since matter is something really distinct [*re ipsa differens*] from form, it has its own unity [*suam habet, sibique propriam unitatem*], since "being" and "one" are convertible'. Matter does not lack unity simply because it is *pura potentia;* unity is common to *actus* and *potentia*. In other words, if matter is one in the composite, where it is actualized, then it is one even when it is only *in potentia* to the composite.

The second concession of an *actus* proper to matter occurs as the Coimbrans are defending the position that matter can exist apart from form. They give the following argument against that position: matter (you say) is *pura potentia;* its *actus,* therefore is just form; so matter existing actually without form would be an *actus* without *actus,* existence without existence.[11] To that they respond with a distinction. Form is the 'substantial' act of matter; but matter when it exists without form has an 'accidental act', so in speaking of matter without form, we are speaking of an accidental act without a substantial act, and in that there is no contradiction. The reply can be clarified with an analogy. Consider the Eucharist: when God ablates the matter of the Host, he conserves the quantity and other accidents of the Host, by substituting his own efficient causation for the material causation that the departed matter had (this claim will be refined in the next section). So too, when God preserves matter without form, he substitutes his own efficient causation for the formal causation of form. Presumably the one miracle is no more difficult than the other.

Suárez

It would seem, then, that in all but name, matter can have an existence of its own, if by that one means existence independent of the 'formal effect of form', which is to give *specific* existence to matter, and to produce a complete substance. So Suárez holds, citing the Coimbrans.[12] He counters their primary argument with what is essentially the Scotist reply.[13] The Coimbrans recognize among *actus* only that of the form in the composite, and the self-subsistent act of spiritual substances. That, Suárez says, is insufficient. There is also the entitative *actus,* which, since matter is really distinct from form, is distinct from the entitative *actus* of form. Less opaquely: matter must have being on its own if it is really distinct from form, even when it is joined to it in the composite (since God could annihilate the form while preserving the matter); that being is the 'entitative' *actus*. Matter, moreover, cannot be *pura potentia* because it has, after all, certain properties. Matter 'desires' form; it adds a perfection, additional to those added by form, to complete substances, and so forth.[14] We have, then, an application of the principle that nothing has no properties, that of nothing nothing can be said.[15]

Nevertheless – here Suárez agrees with Toletus – matter can be called pure *potentia* with respect to the complete substances it may be part of.[16] Indeed, its whole being is simply to receive form: 'for to this it is primarily and *per se* instituted, and thus [. . .] in its essential defining character [*in sua essentiali ratione*] it includes a *transcendentalem habitude* toward form'. We can therefore say that matter is pure *potentia*, provided that the word 'pure' does not connote the exclusion of all *actus* whatsoever.

The stakes

All three discussions agree that *actus* may be understood in two ways. One of them – the specifying *actus* of form in the composite – clearly cannot be an *actus* of matter. Matter does not specify anything; it is what gets specified. The other kind of *actus,* that of existence, can be had by matter. The three discussions likewise agree that the whole being of matter consists in being that which can receive form. In short, the essence of matter is *potentia*. Given that much agreement, it may indeed seem that only a way of speaking, as the Coimbrans suggest, is at stake.

There is, however, something more. Just what it is can be gleaned from two passages. The first, from the Coimbrans, stands at the head of their list of arguments purporting to show that matter is not pure *potentia*:

> Others [. . .], having been overcome, like the Manichaeans, by the burden of insanity, have sunk to the point of saying not only that matter is not pure *potentia* but [of saying that it is] pure *actus* itself, that is, God.[17]

The names of such philosophers, they add, do not deserve even to be mentioned. And they are not.

Nevertheless, if you look at the passage from Albertus Magnus that they cite, you will find the name they refuse to mention. It is David of Dinant, a rather shadowy figure whose work was so effectively suppressed after 1210 that fragments of it surfaced only in this century. Here is a passage from the *Quaternula,* which saw print in 1963.[18] David has been considering whether mind (*mens*) and matter (*hyle*) are indentical:

> With this Plato seems to agree, when he says that the world is God made sensible [i.e., available or perceptible by sense]. For the mind, of which we are speaking, and which we say is one and impassive [*impassibilem*], is nothing other than God. If, therefore, the world is God himself as well as God being perceptible to sense, as Plato and Zeno and Socrates and many others say, the matter of the world is God himself, while the form which comes to matter is nothing other than that which makes God sensible as himself. [. . .] It is therefore manifest that there is but one substance, not only of all bodies, but also of all souls, and this is nothing other than God himself.[19]

The first thing one wants to say on reading this is that David of Dinant was Spinoza four and a half centuries premature. It is not clear what exactly what his reasoning was, but it is easy to see why, for some years after 1210, not only David but Aristotle himself fell into disfavour. Better no philosophy than such philosophy.

Such perversities, it seems, were conceptually not so far away, even in the thought of a Jesuit stalwart like Suárez. In a section entitled 'How pure *potentia* is equivalent to [*aequiparetur*] pure act', Suárez takes up an argument to the effect that prime matter, since it is the thing most distant from God, and since God is pure *actus*, must be pure *potentia.* Distance, Suárez argues, can be understood in two ways: negatively, as between being and nothing, and positively, as between extremes, neither of which is merely the negation of the other. In that sense the North Pole and the South Pole are 'most distant'. Now matter is, as we have seen, certainly not nothing. Nor is it the absence or negation of all perfections, since that is again nothing. Hence:

> Although we admit that pure *potentia* stands furthest from [*summe distare*] pure *actus,* it does not follow that pure *potentia* may not include actuality, since the distance in question is not the greatest compared to [the distance of negation], but rather it is between positive [entities]. Thus it requires some agreement [*aliquam convenientiam*] between the extremes in being [*in entitate*], let this agreement be ever so slight [*est illa convenientia minima sit*].[20]

The disagreement between Suárez and the Coimbrans may be more significant than Suárez is willing to admit at first. Prime matter is, in Suárez's view, both wholly potential and wholly actual. It is not actual by virtue of being a composite of matter and form, of course: with respect to the composite it is purely potential. It is actual by virtue of the identity of, and the 'intimate inclusion' of its entitative act in, its essence. Considered among things that are *in potentia,* moreover, it is indeed perfect of its kind (and in that way it can, like all God's creations, be called 'good'). Prime matter and God alone have a pure actuality, that is, an actuality that does not involve any sort of composition, even the 'metaphysical' composition that obtains in finite spiritual substances. That is, perhaps, the 'agreement' Suárez has in mind in the passage quoted above (although it is possible that he may mean only that both God and matter exist). However slight that agreement was, it was enough, it seems, to put the Coimbrans in mind of a profound heresy, which, though they could not have foreseen it, lay not only in their distant past but in their near future as well.

Prime matter and res extensa

Descartes decided quite early that physics, or 'physico-mathematics', should treat only those properties of matter included within the conception of it as extension. In the extant records of his collaboration with Beeckman, it is unclear to what extent the programme of physico-mathematics is anti-Aristotelian, rather than simply non-Aristotelian. But already in the *Regulae* we see Descartes recognizing that in treating matter as actual extension, for example, he is opposing the view of many Aristotelians according to which matter, though naturally endowed with quantity, is thereby only potentially extended.[21] In *Le Monde,* the matter of his invented world is specifically contrasted with 'that prime Matter of the Philosophers, so thoroughly stripped of all its forms and qualities that there remains nothing which can be clearly understood'.[22] The *Principia* argue that those who hold, as the Aristotelians do, that corporeal substance is distinct from extension, either 'mean nothing at all by the word "substance" or else confusedly think of an immaterial substance to which they then attribute extension – that is, body clearly conceived – as if it were an accident of that substance'.[23]

The Cartesian definition of matter as *res extensa* is sometimes treated either as a preliminary to the geometrisation of physics or as amounting simply to a rejection of secondary qualities on epistemological grounds. Descartes certainly does insist that only a physics in which body is conceived to be *res extensa,* and nothing more, could attain to the certainty of geometric demonstration; the rejection of secondary qualities not only removes from natural philosophy those obscure and confused ideas of sense which cannot serve as the basis for a secure science; it also disqualifies, a priori, any explanation that appeals to sensible qualities, as in fact most Aristotelian explanations do. The Cartesian natural philosopher is thus relieved of any obligation to undertake a case-by-case comparison.

Descartes was doubtless moved by such considerations. Nevertheless, a third interpretation of his definition of matter seems to me to capture a more profound aspect of Descartes' departure from the natural philosophy of his teachers, and to point towards a more lasting consequence of his new physics. The Aristotelians, however much they differed on the essence of matter, agreed that its essence includes being *in potentia* to form. As long as that remains – as long as substantial change is thought to be the actualization of matter's indifferent *potentia* to form – the attribution to matter of quantity, or even the characterization of it as 'indeterminate quantity' that we find in Zabarella, does not take one beyond the bounds of Aristotelian physics. Secondary qualities, moreover, might well be reducible, to temperaments of elemental qualities, and those elemental qualities to tendencies to produce local motion – heat being the power to rarefy, for example. Even the quantification and measurement of qualities, or of 'intensive quantities' like degrees of heat, which we see in Nicole Oresme, and which survives in the graphical representations of motion used by Galileo and Descartes, could have been undertaken within an Aristotelian setting. That the Aristotelians did not dwell on such questions (their disputes on intensive quantity have little to do with what we would think of as empirical physics), that they did not perform experiments to measure intensive quantities, is to be explained, I think, more by reference to the institution in which Aristotelianism was embedded, and to their aims in pursuing natural philosophy, than to any conceptual obstacle in the physics itself.

What is essential to any Aristotelian physics is the basic scheme of change as the *actus* of *potentia,* of form as the *actus,* the perfection, of matter. To that scheme the conception of matter as *res extensa* is entirely opposed. *Res extensa* is at each instant entirely actual: length, width, and depth are all that is required for a thing to be substance; form is superfluous. The only potentiality remaining in nature is divisibility. Divisibility, however, is a *potentia* without an end, an ateleological *potentia.*[24] In Aristotelian physics, the actualisation of that *potentia,* or the division of matter into parts having determinate size and figure, is a mere byproduct of genuine physical change, that is, of the perfection of matter by form.

Divisibility, weak as it is, does save Descartes (but not Spinoza) from going so far as David of Dinant. To be divisible entails at least having, as the Aristotelians put it, 'substantial entitative parts', parts whose existence is independent of the whole and of each other. (I return to this point below.) To have such parts is an imperfection, in the following sense: in principle, at least, one such part could be preserved and the rest annihilated, and thus the whole of which they are parts could be destroyed. God, therefore, cannot be divisible, and cannot be the matter of this world.

Real accidents

The doctrine of 'real accidents', according to which the whiteness of bread, for example, could subsist even if the substance of the bread were annihilated, was the target of more than one Cartesian jibe.[25] The Coimbrans themselves state the obvious objection. God, they write, 'cannot deprive things of their natures'. But 'the nature of an accident would be removed from it, if it cohered by itself outside a subject'.[26] Aristotle teaches that 'the *esse* of accidents is *inesse,* and accidents are by their nature beings of something else, namely, of substance, just as substance is being *per se*'. Substance would no longer be substance, were it to inhere in another; and accidents would no longer be accidents if they did not.

Relinquish so basic a distinction, and chaos, it seems, must follow. Accidents outside substances would deceive the senses, and could not fulfil their ordained role of signifying substance to the senses; separated from matter, they would have no boundaries, and would acquire a boundlessness akin to that of spiritual substances; they would no longer be singulars, but would resemble the Platonic ideas that Aristotle rejects; and finally, since it is less repugnant to suppose a subject without accidents than to suppose an accident without a subject, there could be, literally, a man without qualities, even those that 'certainly, as if by inevitable birth, issue forth from [his] nature'.[27]

The context of these remarks is a series of questions on alteration, based ostensibly on Aristotle's discussion of alteration in *De generatione et corruptione* Book 1, ch. 4, but in fact using that chapter as a pretext to defend the Thomist theory of transubstantiation. In the first of the series, the Coimbrans establish that the subject of inherence of accidents in corporeal substances is, for quantity, matter actualized by form, and for all other accidents, matter by way of quantity (*interventu quantitatis*). Matter must be actualised by form to receive any accident because it itself is *pura potentia*; the interposition of quantity is argued in a variety of ways, notably by appealing to the theological doctrine that after transubstantiation the accidents of the Host, other than its quantity, inhere in its quantity, which for its part inheres in nothing.[28]

In the second question in the series, the Coimbrans argue that in certain cases an accident originally inhering in one subject can, by divine power, be made to inhere in another. More precisely:

(i) No accident that is not really distinct from its subject can inhere in another. Figure, for example, since it is '*idem re*' (the same thing) as its quantity, cannot be transferred to another quantity.

(ii) Any material accident can, by divine power, be transferred to a new material subject; any immaterial accident can exist in another immaterial *or* material subject. If it is transferred to a material subject, it must inhere in it 'indivisibly' – that is, in a point. It cannot exist in an extended part and thereby itself become extended (as whiteness, say, becomes extended, by virtue of the quantity of the bread).

(iii) Quantity and all accidents '*idem re*' with quantity, such as figure, cannot be transferred to an immaterial subject. The primary argument is that it is essential to quantity that it be at least potentially extended; but then the subject in which it inheres must be capable of extension – it must have 'substantial entitative parts', or, in other words, parts that can exist separately as substances in their own right. Actually extended quantity requires such parts because extension consists, as the slogan has it, in having 'parts outside of parts'. 'Outside', applied to parts, requires something like a real distinction between them; immaterial substances have no such parts.

(iv) All other accidents – including, presumably, sensible qualities, though this is not clearly spelled out – can inhere, by divine power, in immaterial subjects. A mind, on this account, could literally be hot, a thought could literally be red.

Two things are worth nothing. First, the primary argument for (ii) (and, according to the Coimbrans, also for (iv), though I do not see exactly how) consists in noting that God can bring it about that an accident should exist *extra subjectum*. This they do not prove until the next question. The rest of the argument is that if it is not incoherent to suppose that an accident can exist outside *any* subject, then it is not incoherent either to suppose that it can exist in *another* subject. (I am reminded here, unfortunately, of the Red Queen, who could believe six impossible things before breakfast. No doubt the first was the hardest; once that was firmly grasped, the other five would follow.)

Second, the exception noted in (i), together with Descartes' view that quantity and the thing quantified differ only in reason, and not *in re*, entail that neither quantity nor figure can be transferred from one subject to another. Hence if the matter of the Host is annihilated and replaced by Christ's body, *none* of the accidents of the Host can remain – its only accidents are extension and its modes. The best Descartes can do to preserve the Thomist account is to show that the Host could be annihilated and replaced, and yet still affect the senses in just the same way. In his response to Arnauld, Descartes hedges: 'I affirm plainly and believe that God can do many things that we are incapable of understanding'.[29] But he goes on to show that the conversion of the Host could occur while leaving the surface of the Host exactly as it was (that is, exactly similar, not numerically identical), and so, since bodies affect our senses only by way of their surfaces, it would look and feel and taste the same. Hence, he notes, after quoting the judgement of the Council of Trent, 'I do not see what one could understand by "the species of the bread", except that surface which is a medium between its particles and the bodies around it'.[30]

I come now to the third question in the Coimbrans' series, the question on real accidents. It is certain, the Coimbrans hold, that 'by God's power' (but not, *pace* Avicebron, by any natural power) accidents can 'be conserved outside a subject'.[31] Citing a wide range of authorities, including the Council of Trent, Patristic authors, and Thomas, they end the statement of their position with a flourish:

> [By these authorities] are refuted and convicted Vuithelepus and Oecolampadius, and others of the same stripe who have boldly opposed the truth of the proposed conclusion, telling us when we assert that accidents can be divinely conserved outside subjects, that the nature of things has been so ordained by God that if substances are removed, accidents must be destroyed and reduced to nothing: Surely these [philosophers], while they wish to be nature's patrons, become deserters of truth, and do an injury to God himself, the prince of nature and the author of all things, when thus they subject God to the decrees of nature, so that (as they contend) nothing can be done by him that exceeds the usual course of things.[32]

Following Thomas, the Coimbrans argue that, because God's power is infinite, he can accomplish without the need of second causes whatever can be accomplished with them, with one exception. The effects of the material cause – the matter of the composite – and of the formal cause – the form of the composite – cannot, in their constitution of the complete composite substance be substituted. God cannot take the place of either the matter of a thing, or its form. He can substitute his activity only for those causes which 'by physical necessity only [and not absolutely] are required'.[33] God can, therefore, cause a human being to be formed without seed, or fire to be made in the absence of fire, or – to come to the case at hand – accidents to be sustained in the absence of their material cause, that is, the subject they would normally inhere in.

In answer to the objection raised at the beginning of this section, the Coimbrans, like Suárez and Fonseca, argue that actual inherence is not the essence of accidents. Rather an accident is 'that which, according to the ordinary law of nature is suited, not to exist by itself, but to inhere in another'.[34] When it exists outside a subject it does not give up its nature and take on that of substance. If it is said to 'imitate substance', this is because like substance, it 'persists by itself, without being sustained [*fultum*] by a substance in which it would inhere'.[35]

I have said enough, no doubt, to try the patience of readers more tolerant than Descartes. I conclude this section with a remark on the implications of the doctrine of real accidents for conceptions of substance and accident generally.

In the notion of substance, as is well known, two ideas have long been entwined. One is that there are ultimate subjects of predication, of which other things may be predicated but which are themselves predicable of nothing. The other is that some things depend for their existence – the precise sense of 'depends' needing to be spelled out – on others, and some do not. There is a strong tendency to unite the two ideas by taking 'depends' and the relation signified by predication to be the same. In the *Principia*, where substance and mode play the roles of substance and accident, there can be no mode which is not actually predicable of a substance; conversely, whatever is not actually predicated of a substance must itself be a substance. The very idea of a thing that, though 'suited, according to the ordinary law of nature' to inhere in another, in fact does not, is incoherent. So Descartes writes in his response to Arnauld that 'the human mind cannot think that the accidents of the bread are real and yet exist without their substance, unless at the same time it conceives them in the mode of substance'.[36] Given the dedicated attempts of Suárez, the Coimbrans, Fonseca and many others to do what Descartes says *cannot* be done, the remark must have taken aback some of his contemporaries.

Taking into account Descartes' definitions of the real and modal distinctions, the point can be put more tellingly. There are no facts by which to distinguish substances from modes except facts of the form: by God's absolute power, *X* can (or cannot) exist without *Y*. Those facts alone determine whether a thing exists in the manner of a substance or in the manner of a mode. For the Aristotelian, on the other hand, there is more to be said. The whiteness of the Host can, by God's power, subsist apart from the Host, and so too the Host can exist apart from its whiteness. The whiteness, in fact, can exist apart from all other finite things. It 'imitates' substance; by Descartes' definition, it *is* substance, whatever the theologians might say. But for the Aristotelian something else enters into the account: namely, that 'according to the ordinary law of nature' whiteness is not suited to exist by itself. It has, as part of its nature, an 'aptitude' toward a subject, which may or may not be fulfilled, just as a human being may or may not learn to speak. That aptitude, and not actual inherence or subsistence *per se*, is what makes it an accident.

To be an accident, then, rather than a substance or a mere mode (in the Aristotelian sense) like figure, is to occupy a certain rung on the ladder of perfection that runs from matter, *pura potentia,* to God, *purus actus*. Accidents, because their nature includes an aptitude to inhere in a subject, are inferior both to the incomplete substances – form and matter – that include an aptitude toward each other, but not in the mode of inherence, and to complete material substances; those are in turn inferior to spiritual substances, which are simple, and whose forms do not have any aptitude toward matter.

Conclusion

Descartes was not mistaken when he took the Coimbra commentaries to represent the position of the 'grande Société'. They are, as their title pages indicate, a corporate production: of the Collegium Conimbricensis, of the Societas Jesu. Though no work would pass judgement by the Office of the Holy Inquisition if it contained anything 'repugnant to Faith or good morals',[37] the Coimbra commentaries, like the Complutensian commentaries of the Carmelites, had the special burden of representing the group under whose name they were published, not indirectly through an individual who could be repudiated, but directly.

In such a work one does not expect surprises. The occasional expressions of a personal point of view that one sees here and there in Toletus or Suárez, or the novel, and therefore untested, sytematizations of metaphysics and psychology undertaken by authors like Suárez and Arriaga, will not be found. The closest that their author comes to revealing himself is in the heightened tone of certain passages – the diatribe against the unnameable David of Dinant, the scorn heaped on those who would subject God to nature's laws – and in his sensitivity to the Manichaean positions, as if he were fighting some of Augustine's battles again.

What one finds instead is a Latinity purged of scholastic barbarities (as the humanists called them), a clear ordering within each question of the authorities and arguments on each side, the inclusion of *recentiores* like Vesalius, Fernel, and Ficino, and occasionally the arrangement of questions into brief treatises, reminiscent on the one hand of some of Thomas' collections of disputed questions, and on the other of the much more thoroughgoing restructuring of the materials of metaphysics by Suárez. The commentaries impress the reader with their erudition, but in the period that was commonplace. What strikes me more, when I compare the Coimbrans' work with that of, say, Buridan, Zabarella, or the later Jesuit textbook of Arriaga, is its readability. Goes may get bogged down in logical murk (it was Fonseca, after all, who wrote the logic commentary), but the brevity of his articles, which seldom run more than a few pages, ensures that there will not be long stretches of unparagraphed text that fatigue the eye, or multiple bouts of reply, counter-reply, and counter-counter-reply that strain the memory. If Aristotelianism could have been renewed, here was its best opportunity. Here, too, one supposes, was a model for the young Descartes.

Philosophically, the commentaries offer what one might prematurely call an enlightened Aristotelianism. After arguing, against Aristotle, that the female concurs actively in generation, the Coimbrans write that to follow the 'prejudged authority', even of one who like Aristotle 'excels in ingenuity' at the expense of truth is 'most alien' to a 'true Philosopher'. For that reason,

> we have perforce in this controversy, as in some of those that we engage in below, to leave Aristotle behind, in cases where experience has persuaded us to do so, and especially [the experience] of the art of anatomy, which after Aristotle's time was more vigorous and more familiar.[38]

Aristotle is an authority, he is *the* Philosopher; the presumption is in his favour, but it is only a presumption. It can be overruled by faith or by experience. Even if, considering the Coimbrans' overall adherence to their authorities and the apologetic aim of their project, one takes the declaration to be little more than lip service (as many seventeenth-century critics of Aristotelianism did), still the invocation of experience, and the assurance that we – that is, philosophers in the age of Fernel, Vesalius, Valles, and other *recentiores* – are capable of advancing beyond Aristotle and Thomas, places the Coimbrans, not certainly at the forward edge, but in the solid middle, of the philosophical Renaissance.

I am not sure, finally, that 'Descartes and Coimbra', in the sense in which that would be usefully contrasted with 'Descartes and Suárez', or 'Descartes and Rubio', is a fruitful object of study. It is one thing to take the Coimbra commentaries to represent an updated Thomism, and Descartes to be responding to that rather vaguely characterized phenomenon; another to try to dissect out specifically Coimbran components in his philosophy or his version of 'the Philosophers'. Descartes seems to have paid little attention to those categories, his fixation on the Jesuits aside; it is not clear that we will benefit by treating him as if he did. Perhaps the best guide lies not in textual correspondences or hypotheses about what he may have read and what of that retained, but rather in the reception of his philosophy. Was he, in other words, apprehended by contemporaries as slanting toward the Thomists, or against the Scotists? It is, of course, possible for a debt or a *parti pris* to go unnoticed or unmentioned. Descartes, in any case, did not advertise his debts, and like the Philosophers themselves, he mostly left his opponents unnamed. Yet it would be odd if his leanings (or even his leanings mistakenly perceived) should have escaped those who were well attuned to such things, like Arnauld. My hunch is that Descartes, in whose philosophy so many of the old questions become moot, was not apprehended in that way. He was, in that sense, just what he hoped to be: no longer Aristotelian.

Notes

1 I have used the following abbreviations:

Coimbra, *In de Gen*: Coimbra [Collegium Conimbricensis], *Commentarii Collegii Conimbricensis* [. . .] *in duos libros de generatione et corruptione, Aristotelis Stagiritae* (Lugduni, 1606).

Coimbra, *In Phys.*: Coimbra [Collegium Conimbricensis], Commentarii Collegii Conimbricensis [. . .] in octo libros physicorum Aristotelis Stagiritae [. . .] (Lugduni, 1602).

David of Dinant, *Quaternuli*: David of Dinant, *Quaternulorum fragmenta.* ed. M. Kurdzialek (Warsaw, 1963: Studia Mediewistyczne 3).

Fonseca: *In met*: Fonseca, Petrus, *Commentariorum Petri Fonsecae Lusitani [. . .] in Libros metaphysicorum Aristotelis* . . . (Cologne: Lazarus Zetzner, 1615). (Facsimile repr. Hildesheim: Olds, 1964).

Scoraille 1912–13: Scoraille, Raoul de, *Francois Suarez de la Compagnie de Jesus: d'apres ses lettres, ses autres ecrits inedits et un grand nombre de documents nouveaux* (Paris, 1912–13).

Suárez, *Disp*: Suárez, Franciscus, *Disputationes metaphysic.* (Hildesheim, 1965: reprint of vol. 25–26 of the *Opera*.)

Suárez, *Opera*: Suárez, Franciscus, *Opera omnia.* ed. D.M. André (Paris, 1856).

Toletus, *In Phys*: Toletus, Franciscus, *Commentaria unà cum Quaestionibus in octo libros Aristotelis de Physica auscultatione.* In *Opera*, vol. 4. (First printed 1572, with numerous subsequent editions.)

Toletus, *Opera*: Toletus, Franciscus, *Opera omnia Philosophica* (Cologne, 1615–16). (Fascimile repr. with intro. by Wilhelm Risse. Hildesheim, 1985.)

2 Descartes to Mersenne, 30 Sep 1640, AT iii. 185.

3 Descartes to Mersenne, 3 Dec 1640, AT iii. 251.

4 Descartes to Mersenne, 11 Nov 1640, AT iii. 233.

5 Descartes to Mersenne, 22 Dec 1641, AT iii. 470.

6 Concerning the commentaries Suárez is thought to have written in his early years as a professor of philosophy, see Raoul de Scoraille, *Francois Suarez de la Compagnie de Jesus: d'apres ses lettres, ses autres ecrits inedits et un grand nombre de documents nouveaux* (Paris, 1912–13), ii. 412–16.

7 AT vii. 235.

8 *In Phys*, 205.

9 *In Phys*, 205F.

10 *In Phys*, 212E.

11 *In Phys*, 218A-B.

12 Franciscus Suárez, *Disputationes metaphysicae* (Hildesheim, 1965), 13 §5 no. 3; *Opera omnia.* ed. D.M. André (Paris, 1856), xxv. 414.

13 Ibid no. 5; xxv. 415.

14 It is worth noting also that Suárez, unlike more faithful Thomists, believes that some accidents, notably quantity, inhere in matter itself, even if it is not actualised by form (*Disp.* 14 §3 no. 10; *Opera* xxv. 474).

15 '[. . .] Material, by its nature has a transcendental perfection and goodness [. . .] For it is certain that the composite of matter and form is more perfect than form alone; and so matter has a perfection, which it adds to the composite. Or again, matter is capable of appetite [i.e. of tendency to form] [. . .]; and therefore it has by its nature its own perfection: but perfection cannot be understood without actuality, at least transcendental [i.e. abstracting from the categories]. *Disp.* 13 §5 no. 9; *Opera* xxv. 416.

16 Ibid no.11; xxv. 417.

17 *In Phys*, 207C

18 David of Dinant, *Quaternulorum fragmenta.* ed. M. Kurdzialek (Warsaw, 1963).

19 lxx. 24–lxxi. 4 = f. 214vb–215ra

20 13 §5 no. 19; xxv. 420

21 *Regulae* 14; AT x. 447.

22 *Le Monde* 6; AT xi. 33.

23 *Principes* II art. 9; AT ix-B. 68.

24 Divisibility (as the suffix '-ible' indicates) is a *potentia* in a broad sense (i.e. one in which there is no connotation of propensity or fitness; among the Aristotelians one finds talk of '*potentia logica*', for example, meaning logical possibility, where there is no suggestion of any *tendency* for what is logically possible to occur). But the divisibility of quantified matter has no role in Aristotelian physical explanation except as a condition of possibility for natural change (e.g. corruption, when the body falls apart). Thus for Descartes, divisibility, the only quality of *res extensa* that even *looks* like an Aristotelian *potentia* (I am setting aside the complicated question of force), is admissible just because it is, from the Aristotelian standpoint, not the sort of quality that would be appealed to in efficient or final causal explanation. In that sense, it is a- (or non-) teleological.

25 'It is of no use for them to say that this heaviness is not a substance; for truly they conceive of it in the likeness of substance, insofar as they judge it to be real, and that by some power (namely, Divine power) it can exist apart from the stone.' (To Arnauld, 29 Jul 1648; AT v. 223). See also the Fourth Replies, esp. AT vii. 252–3.
26 *In de Gen.* 1 c4 q6a1; 72.
27 Ibid, 73.
28 *In de Gen.* 1 c4 q4; 59
29 AT vii. 249.
30 Ibid, 251.
31 *In de Gen.* 1 c4q 6a2, title; 73.
32 1 c4 q6a2; 74
33 Ibid, 75.
34 1 c4 q6a3; 76–7.
35 Ibid.
36 AT vii. 253.
37 *In de Gen.*, 'Judicium'
38 *In de Gen.* 1 c4 q27a2; 194. Cf. Fonseca, *In met.*, 7 c2 q1§2–3; 3:198–201.

2 Descartes' debt to Beeckman

Inspiration, cooperation, conflict

Klaas van Berkel

When René Descartes left France in 1618 and went to the Dutch Republic, he had, as is well known, the good luck to meet Isaac Beeckman. Meeting the Dutch philosopher, who was born and raised in Middelburg, had studied theology and mathematics in Leiden, had earned a living as a candlemaker for a while and had just received his MD in the French university of Caen, proved to be of vital importance for Descartes' career. Without the stimulus of Beeckman the somewhat disillusioned Descartes might never have found his way back to science and philosophy. In the city of Breda, Beeckman and Descartes discovered that they were both very much interested in physical and mathematical problems. There Descartes learned from Beeckman that only by a proper integration of mathematics and natural philosophy could physical problems be solved. They became intimate friends and, when Beeckman left Breda on 1 January 1619, Descartes presented him with his *Compendium musicae*, as a token of his friendship ('*familiaritatis nostrae mnemosynon et certissimum mei in te amoris monimentum*'). Descartes exchanged some letters with Beeckman before he went away, and he even tried to visit his friend in Middelburg, but their collaboration came to an end, and for almost ten years they would not see each other again.

In 1628, Descartes, by now a philosopher with a well developed sense of his mission in the world, returned to Holland and immediately renewed his friendship with Beeckman, who by that time had become the very respectable head of the Latin school in the city of Dordrecht, the oldest city of the province of Holland. But this time their friendship did not last very long. By October 1629 Descartes had, much to Beeckman's surprise, broken all his ties with the Dutch schoolmaster. When Beeckman asked for an explanation in 1630, Descartes wrote him two very sharp and revealing letters in which he tried both to deny any influence exercised by Beeckman and to ridicule any claim to originality by Beeckman. Although some years later Descartes and Beeckman were on speaking terms again, their old affection never returned. After Beeckman's death in May 1637 Descartes reacted rather coolly. Although on 14 June he wrote to Andreas Colvius, one of Beeckman's best friends, about 'the sad news of Beeckman's death', in a letter to Mersenne less than two weeks earlier he had still counted Beeckman among the men 'who try to acquire some reputation without deserving it'.[1]

Scholars have devoted more attention to the first phase of Descartes' friendship with Beeckman than to their quarrel in 1629 and the following years. Ever since Cornelis de Waard's discovery of the *Journal*, and especially since Alexandre Koyré's painstaking analysis of this episode, the meeting of Beeckman and Descartes in 1618 has been considered to be one of the crucial episodes in Descartes' life. In 1618 Descartes was still in his formative years and in order to understand the development of his philosophy it is essential to analyze, down to the least detail, his interaction with Beeckman. By 1630, on the other hand, Descartes seemed to know what his fundamental ideas concerning physics and philosophy were. Because of this, it has looked as though an analysis of the clash between Beeckman and Descartes would not teach us very much about his philosophy. In a strictly philosophical perspective, this episode in Descartes' life may seem uninteresting and one can understand why so few scholars have devoted their attention to it.

Yet there are other reasons for studying this episode. In the first place, the idea that Descartes developed his philosophy from fundamental ideas he had established early in his career has now become obsolete. We tend to see him as a philosopher who adapted to new environments and reacted to new situations. Therefore, the episode of his quarrel with Beeckman may after all have some relevance for understanding the unfolding of his philosophy. It may even force us to reconsider some aspects of their co-operation in 1618–19. And in the second place, this story tells us a lot about the personalities of both Descartes and Beeckman and, since personalities are nowadays not considered to be totally irrelevant even in philosophical contexts, we would be well advised to take a second look at the conflict between Beeckman and Descartes.

So, elaborating on what has already been said on this topic and focusing on some elements that have not had the proper attention of scholars, in this essay I will try to address three issues. First, and rather briefly, I will ask what was the nature of their co-operation in Breda in 1618. Then I will try to determine the reasons why Descartes had his quarrel with Beeckman. Finally I will speculate on the reasons for his reacting so vehemently to Beeckman's claims to originality and his rather curious efforts to calm down his former friend.[2]

Before the discovery of Beeckman's *Journal* by Cornelis de Waard in 1905, few scholars could have guessed that an obscure Dutch philosopher, Isaac Beeckman, would have played a crucial part in the story of the unfolding of Descartes' philosophy. But when De Waard read through the manuscript he had found in the provincial library of Zeeland, he realized that the history of Cartesian philosophy had to be rewritten. Beeckman's *Journal* contained precious evidence of the close ties between Beeckman and Descartes and, in particular, Beeckman's notes concerning mechanics and music suggested that it was actually Beeckman who had put Descartes on the road to his mature philosophy. The excerpts in the Adam and Tannery edition of Descartes' works, De Waard's own articles, and finally Koyré's detailed reconstruction of the discovery of the law of falling bodies, turned Beeckman into a prominent figure in the history of early modern science and philosophy. Many agree with Koyré when he wrote about Beeckman that:

> He seems to us a link of the greatest importance in the history of the development of scientific ideas; and finally we can now see his influence on Descartes was far deeper than has hitherto been supposed.[3]

Still, even after the discovery and analysis of Beeckman's *Journal*, there were historians of philosophy, mainly in France, who found no place for Beeckman in their reconstruction of the history of Cartesian philosophy. One of them, in a paradoxical vein that is so characteristic of French intellectuals, maintained that 'the meeting of Descartes and Beeckman in 1618 is of very great importance in the history of thought, but it is a simple occasional cause, leaving no trace or bearing on Cartesian philosophy'.[4] Even Geneviève Rodis-Lewis, in her recent biography of Descartes, tends to play down the influence Beeckman exerted on Descartes. Of course, she too cites the excited Descartes who, after meeting Beeckman in the streets of Breda and discussing with him problems of mechanics and music, is lyrical about his older friend. He calls Beeckman the promoter of his studies and its first author: 'Really you are the only one who has reawakened me from my idleness'.[5] An echo of the praise is to be found in Beeckman's own words:

> This man from Poitou has conversed with many Jesuits and other scholars and learned men. However, he says he had never found someone, except for me, who is accustomed to study in the way I prefer and accurately joins mathematics with physics.[6]

But in the end, Rodis-Lewis still seems to restrict Beeckman's role to that of the man who unlocks what would have been unlocked anyway. 'If they had not met, when would Descartes have ceased to be an idle disappointed soldier?', she asks, as if Beeckman was important not for what he had to say but only for the moment he said it. Whatever the content of their conversation, Descartes soon outgrew his Dutch mentor. His juvenile essays were certainly not what we understand as Cartesian philosophy, but they were, according to Rodis-Lewis, 'more original than anything Beeckman had written'.[7] Beeckman showed Descartes the relevance of mathematics to natural philosophy, but he never seems to have understood how crucial mathematics might be in rebuilding philosophy. Beeckman's so-called '*philosophia physico-mathematica*' was far inferior to Descartes' mathematically inspired natural philosophy as developed in his *Discours de la méthode* of 1637. There was inspiration, so Rodis-Lewis seems to suggest, but no real influence.

Without being able to make a sharp distinction between inspiration and influence, I think there was a real influence of Beeckman on Descartes and not just some vague inspiration. First of all, not only did Beeckman suggest an integration of mathematics and natural philosophy, he also provided Descartes with some striking examples of a mathematical natural philosophy. Together they worked on the law of falling bodies, Beeckman adducing the natural-philosophical presuppositions (such as his principle of inertia) and Descartes working out the mathematical solution (which he misunderstood himself, but that is not the issue). A second example is Beeckman's proof that pitch is directly proportional to the length of a string. Of course, these are unrelated examples of a combination of elementary mathematics and rather crude physics. But it is not the simplicity or the complexity of the solutions that is at stake, it is the principle as such which counts. Using mathematical reasoning in natural philosophical questions went against the grain of Aristotelian natural philosophy. Beeckman showed Descartes not only that such a combination was legitimate, he also showed that it worked.

Second, Beeckman implicitly confronted Descartes with a geometrical and corpuscular world view that proved essential to all Descartes' thinking too. It is uncertain whether in 1618 Beeckman had already showed Descartes what he had written in his *Journal* up to that point. It is usually assumed that Descartes had already been able to glance through the *Journal* by that time, but actually there is no direct proof for that. It is indeed quite likely that it was only in 1628 or 1629 that Descartes had access to the *Journal*, by then a book bound in calf instead of a loose collection of manuscripts.

Between 1626 and 1628 Beeckman reorganized his rather chaotic bundle of manuscripts, had someone make a fair copy on the same format as the notebooks from his youth, and added headings in the margins to most of the notes. At that time, he considered the question whether to show his writings to others. Publishing his findings was certainly something Beeckman did not find attractive: he was afraid of being laughed at if elementary mistakes were detected. But, on the other hand, to keep it secret or to show it only to one good friend would be too restrictive. In the end Beeckman decided to show his *Journal* not to one, but to three friends: first Descartes, then Mersenne, and finally Martinus Hortensius also had access to the *Journal*.[8] Descartes therefore must have had this privilege after 1626, most likely in late 1628 when they discussed what they had done since early 1619. Another argument for the idea that Descartes did not see the *Journal* in 1618 is to be found in the words Beeckman later used when discussing their exchange of ideas in Breda. To Mersenne he wrote that the scientific problem Mersenne posed to him was actually the very same problem he himself had 'communicated' ('*communicavi*') to Descartes in 1618. This clearly implies an oral communication. If Beeckman had shown Descartes one of his notebooks, he certainly would have used a different expression.

An argument against my thesis might be that, as Gaukroger has pointed out, Descartes' very first writings, his *Olympica*, *Praeambula* and *Experimenta*, all dating from early 1619, in their presentation clearly show an indebtedness to Beeckman's *Journal*.[9] It looks as if Descartes started his own *Journal* having seen the example set by Beeckman. Rodis-Lewis however suggests that Beeckman had given Descartes a notebook as a New Year's gift (in return for Descartes' *Compendium musicae*), perhaps with the fatherly advice to use these books as any schoolboy had to do, without however letting Descartes see what he had written in his own book.[10] In that case, Descartes can only have *heard* about Beeckman's atomistic or at least corpuscularian world view. But whether or not Descartes had seen the *Journal*, a crucial element of Beeckman's physico-mathematical reasoning was his notion that matter consisted of small particles in motion. The fact that pitch is proportional to the length of a string is explained by the fact that a short string moves up and down more often than a longer string and therefore cuts the crude particles of air into smaller parts, which then cause a higher pitch. In his *Journal*, Beeckman explicitly mentions – in the context of his conversations with Descartes – his so-called 'υποtheses', which include, besides the 'principle of inertia', his corpuscularian world view. These notions, crucial for Descartes' mechanistic world view as expounded in *Le Monde* or the *Principia philosophiae*, were as important to Descartes as were his mathematical proofs of certain physical phenomena. Of course, Beeckman was not the first to confront Descartes with atomistic or corpuscularian notions, but as with the integration of mathematics and natural philosophy, in the case of Beeckman Descartes saw how fruitful these notions could be. So, rather than merely inspiration, there is every reason to talk about the influence of Beeckman on Descartes. The very fact that in 1629 and 1630 Descartes was so anxious to deny any influence on Beeckman's part clearly shows that there was something to argue about: not only inspiration, but influence too.

Almost ten years elapsed before Beeckman and Descartes met each other again. For reasons that are not altogether clear, Descartes decided in 1628 to leave France and to move to Holland. Perhaps he hoped to find the peace and quiet he needed to develop some of his ideas further or to continue with his experimental work. In the autumn of 1628 he travelled to Holland and on 8 October he presented himself to Beeckman at the Latin school in Dordrecht. We do not have much information on this meeting, but from the warm expressions of friendship and admiration in the notes in Beeckman's *Journal*, we may safely conclude that both Beeckman and Descartes very much welcomed this opportunity to renew their collaboration. Descartes told Beeckman about the things he had done since 1618 and he in fact asked Beeckman to work with him on the further elaboration of his thoughts. During all his travels through France, Germany and Italy, so Descartes told Beeckman, 'he had not found anyone with whom he could discuss his ideas as freely and from whom he could expect so much help in pursuing his studies'. Beeckman too was full of admiration. He told Descartes that he had never met or read a mathematician as gifted as Descartes.[11]

By 11 November, Descartes was back in Paris.[12] Beeckman was especially intrigued by Descartes' new 'general algebra' and when Descartes returned to Paris in order to make some further arrangements before settling in Holland permanently, he promised to send his Dutch friend a copy of his still unpublished *Algebra*. In January 1629 this little treatise did indeed arrive in Dordrecht and Beeckman copied some of Descartes' notes in his *Journal*.[13] In the letter accompanying this treatise, Descartes also approved of Beeckman's solution of a mathematical problem Descartes had left behind on his leaving Dordrecht in the autumn of 1628.

It was in March 1629 that Descartes finally settled for good in Holland. On his way to Amsterdam he once again visited Beeckman in Dordrecht.[14] From Dordrecht, he travelled to Amsterdam, where he arrived on 28 March, and from there he went on to the university town of Franeker in Friesland. Descartes matriculated as a student in Franeker on 26 April, but he had not forgotten Beeckman. When he tried to persuade his instrument-maker Guillaume Ferrier to come to Franeker and continue their experiments, he told Ferrier that he would do well to travel through Dordrecht, in case he needed some extra money for travelling to Franeker, and Beeckman, on seeing his – Descartes' – letter, would without doubt be prepared to give Ferrier whatever he needed.[15]

Such was the relationship between Beeckman and Descartes at the beginning of 1629. But in the meantime something else had happened. In 1628 Marin Mersenne tried to get in contact with Beeckman and by way of introduction he had André Rivet, a mutual friend who was a Walloon minister and professor of theology in Leiden, send some problems in acoustics to Beeckman, challenging him to solve these problems.[16] Beeckman apparently responded to Rivet by saying that he had already solved these problems in 1618 when he and Descartes had been working on them in Breda. He assumed that Descartes had given these problems to Mersenne, without knowing that Mersenne would pass them on to the man who had already solved them for Descartes.[17] In March 1629 Beeckman wrote to Mersenne again on the same topic. He praised Descartes highly, but he also wrote:

> This is the man to whom I have already ten years ago communicated [*communicavi*] the things I have written concerning the causes of

> consonances, and it is this man who, as I assumed, has suggested to you the ideas for this question.[18]

In September 1629 Mersenne told Descartes about this incident and Descartes, perhaps to Mersenne's surprise, reacted in a rather annoyed way. In his letter to Mersenne written on 8 October, Descartes interpreted the words used by Beeckman as saying that he, Beeckman, had been Descartes' teacher in Breda, 'that he had been my master ten years ago'.[19] He thanked Mersenne for warning him and decided not to correspond with Beeckman any longer. In fact his only letter to Beeckman was one asking him to return the copy of the *Compendium musicae* Beeckman had received as a New Year's gift in 1619.[20] He did not tell Beeckman why he wanted him to return this treatise. In a letter to Mersenne of 18 December 1629 Descartes, who by now was living in Amsterdam, expressed himself rather negatively about Beeckman's talents as a natural philosopher. He suggested that Beeckman had learned the principle of inertia, so central in their formulation of the law of free falling bodies in 1618, from him, while in fact it had been the other way around.[21] To Descartes, the fact that Beeckman had given another French visitor, Gassendi, a copy of his 1618 *Theses de febre tertiana intermittente* (with some very fundamental corollaries concerning the principle of inertia and the atomic structure of the world), only proved Beeckman's lack of original ideas. Presenting Gassendi with this dissertation, defended in September 1618, sufficiently proved 'that he had done nothing since then that was any better'.[22] It is perfectly possible that Descartes was not aware of the content of Beeckman's dissertation and so did not know that in the corollary Beeckman had been the first to state a principle of inertia that sounds modern. The copy of the *Theses* De Waard used for his edition of Beeckman's *Journal* was not part of the manuscript (read by Descartes at least by 1628), but was found in the British Library. In the *Journal*, Beeckman had formulated most of his corollaries by August 1618 – so before the defence of his dissertation[23] – but the thesis concerning inertia is missing there.

In August 1630, Mersenne visited Beeckman in his home in Dordrecht. The French philosopher was touring the Low Countries and after a short stay in Leiden paid his respects to Beeckman. As a token of his friendship Beeckman allowed Mersenne to read his *Journal*, Mersenne being the first after Descartes on whom this honour was bestowed. Turning over the pages of the *Journal*, Mersenne soon discovered that Descartes had given a completely false impression of Beeckman's abilities and of the relationship between the two of them. Mersenne now suddenly realized that Descartes had passed off as his own, ideas he had taken from Beeckman.[24] Mersenne thus felt free to inform Beeckman of Descartes' opinions and of Descartes' reasons for putting an end to their relationship. Of course, Beeckman was very surprised and disappointed and he immediately wrote to Descartes asking him for an explanation. Mersenne did the same.[25] At first Descartes did not react, but after a letter from one of Beeckman's colleagues at the Latin school in Dordrecht urging him to respond, Descartes realized that his reputation was at stake and sat down to write a letter to Beeckman.

The letter, written at the end of September or the beginning of October 1630, was condescending. Descartes told Beeckman that he should not have taken his compliments at face value. This was just the French way of being courteous. But setting aside this misunderstanding, it was a plain fact that Beeckman had learned more from Descartes than the other way around. And even if Beeckman thought he could prove from what he had recorded in his *Journal* that Descartes had learned something from him, Descartes warned him to be cautious. His friends knew that he was used to learning something even from worms and ants, implying that Beeckman ran the risk of being compared to a worm or an ant. Nevertheless, because of their old friendship, he, Descartes, was perfectly willing to forgive and forget.[26] But Descartes did not get away with it that easily. In his reply – which is only partially extant – Beeckman probably summed up what according to him (and Mersenne) Descartes had derived from his conversations with Beeckman.[27]

On reading this letter, Descartes was infuriated. In a long letter of 30 October 1630 he hit back hard and tried to crush Beeckman, at least psychologically.[28] He turned down any suggestion for reconciliation made by Beeckman and accused him of writing to him as if he were one of his pupils. What Beeckman thought were important issues in natural philosophy were in fact not much more than trivial things, interesting perhaps for a beginner, but not for someone like Descartes. And so that Beeckman might not make the same mistake again, Descartes then set out what is implied when someone is influenced by someone else and in what way Descartes could have been influenced by Beeckman.

Descartes denied right from the start that he had derived something of importance from Beeckman. He, Descartes, only held certain convictions because by his own reasoning he had accepted them. The fact that others had the same convictions was in his view of no importance. It would only be of importance if Descartes had been led by the authority of someone else or had accepted his arguments without fully understanding and accepting them, but this was not the case. Descartes had only been led to adopt particular convictions by the truth of these convictions and by nothing else. Even if Beeckman and Descartes had had the same convictions, Beeckman's influence would be out of the question because Descartes' argumentation would prove to be much better than Beeckman's. It is evident that in order to rule out any influence exerted by Beeckman on Descartes the latter had to entertain a very restricted concept of influence. Descartes seems to be saying that one is only influenced by someone else when one accepts the wrong ideas, or the right ideas for the wrong reasons.

Perhaps Descartes realised that this was a rather superficial sophism, because he also adduced some other reasons for denying any influence exerted by Beeckman. After all, he asks, what kind of discoveries do you actually have in your *Journal*? In general, there are three kinds of discoveries. The first, the really important ones, can only be made by a very strong intellect and thus only belong to those who made these discoveries. But because these discoveries are so dependent on a strong intellect and can only fully be understood by such a person, there is no need to be afraid of these discoveries being stolen by someone else. Since Beeckman was so possessive of his ideas, they could not belong in this first category. The second kind of discoveries are discoveries made by chance. Now, because everybody has luck sometimes, it is quite understandable that someone who made such a discovery is anxious to keep it to himself. The third kind of discoveries are findings of a lesser sort, trivial discoveries hardly worth communicating, but treasured by their discoverer as if they were of great importance. In this case, such a man acts like a fool who has filled his box with pieces of glass and small stones found between the rubbish of his neighbours, treating them as if they were a great treasure. 'I do not want to compare your manuscript to such a box,' Descartes added maliciously, 'but in my opinion therein one can hardly find something that is more interesting than some pieces of stone and glass'.[29]

We do not know how Beeckman reacted to this letter. Was he intimidated, was he angry, or did he just shrug his shoulders after reading this infamous 'review' of his *Journal*? Perhaps he did all three at the same time. But whatever his reaction, we know that after a while Beeckman's relations with Descartes were more or less back to normal. In October 1631 Beeckman went to see Descartes in Amsterdam and Descartes visited Dordrecht shortly thereafter.[30] De Waard's reconstruction was that Descartes visited Beeckman in Dordrecht before Beeckman went to see him in Amsterdam, whereas Rodis-Lewis thinks it was the other way around.[31] Since Beeckman reports that he visited Descartes while the French philosopher was recovering from a serious illness, we may safely assume that Beeckman – moved perhaps by Descartes' illness – was the first to make a gesture. These visits were repeated later on, and they occasionally wrote a letter to each other. In 1634 Beeckman also was so kind as to lend his copy of Galileo's *Dialogo* to Descartes for a few days. Nevertheless, the old cordiality and friendship never returned. For us the question remains: why did Descartes react so vehemently to the suggestion that he had learned something from Beeckman?

There is no serious historian of science who simply believes Descartes was right when he denied any influence exerted on him by Beeckman. Descartes' three categories of discoveries may represent an interesting way of looking at scientific discovery, as Gabbey has argued, but this does not necessarily lead to the conclusion that Beeckman's ideas belonged to the third, the trivial kind.[32] Therefore, most historians have looked for external reasons for Descartes' anger, reasons that are external to the scientific and philosophical ideas of the two men.

Some have sought a psychological explanation and suppose that the quarrel between Beeckman and Descartes was at bottom a clash of personalities. This for instance is how Gaukroger in his biography of Descartes interprets Descartes' overreaction. He agrees with Floris Cohen that what we have here is a clear case of 'psychological projection'.[33] Descartes' indignation about Beeckman's putative boasting and representing himself as Descartes' master only reflects his own obsession with 'praise' and 'being taught'. He also sees the dispute as an example of intellectual patricide. In 1618 Beeckman, although only eight years older than Descartes, acted as a father figure for the young man from Poitou. But by 1630 Descartes had become, at least in his own view, a completely independent philosopher and the mere suggestion of Beeckman boasting that he had been his master was enough to enrage Descartes. By psychologically and scientifically destroying Beeckman he would for once and for all gain independence and free himself of any suggestion of indebtedness to others.

But perhaps explaining Descartes' overreaction in terms of his psychological needs is not all there is to say about it. In a way, Descartes may really have felt threatened by Beeckman's insistence on having been the one to come up with some ideas first. At first, on being informed by Mersenne about a casual remark by Beeckman, Descartes may have thought that by just ignoring Beeckman he could suppress any suggestion of dependence. But the letter of Beeckman of October 1630, which is unfortunately lost, must have contained some very specific arguments showing in what sense Beeckman had taught Descartes certain things. This time Descartes had to react differently. By now he had started working on a general treatise on natural philosophy which eventually came to be known as *Le Monde*. According to Gaukroger, Descartes had completed at least the first five chapters by February 1630, which set out the basic 'ideas concerning matter and motion'.[34] In these chapters Descartes sketches his micro-corpuscular natural philosophy and treats some of the general problems connected with it (the existence of the void, the nature of liquidity and hardness and so on). He was working on the chapters following this introduction when he received the letters of both Mersenne and Beeckman, and suddenly realized that Beeckman could well jeopardise the whole enterprise he was working on. If Beeckman were to publish some of the ideas he said he had communicated to Descartes, Descartes' claim to have developed a totally original and completely new philosophy of nature would be in ruins.

This fear was not totally unfounded. Beeckman's letter must have reminded Descartes of something the Dutch schoolmaster had told him when Descartes had the opportunity to consult Beeckman's *Journal* at his house in Dordrecht in 1629 (perhaps Beeckman also reminded Descartes of it in his letter). In 1629 Beeckman had plans to publish his basic ideas concerning his mechanical philosophy and he had been collecting the most important notes in his *Journal* for such a publication. Since these notes contain just the elements Descartes had used for the foundation of his natural philosophy, Beeckman's publication, even if he only published the raw material of his *Journal*, would destroy his own claims to originality in this field. Descartes' angry letters must therefore have been intended as a means of discouraging Beeckman in carrying through his plans for publication. Of course, if at that time Descartes only intended to publish his natural philosophy as a consequence of a general philosophical system, metaphysically legitimated and logically deducted from first principles, he would have had nothing to fear from Beeckman's plans. But I agree with Gaukroger that this was not the way in which Descartes had been working on his philosophy. He was not a metaphysician deducing a natural philosophy from metaphysical principles, but a natural philosopher who over the years came to realize that he needed some sort of metaphysics as a basis for his natural philosophy. When Beeckman claimed to have had some specific influence on Descartes, Descartes was not yet sure about his philosophy and therefore had every reason to fear a possible rival in natural philosophy.

Beeckman had never really worked towards a publication of his basic ideas concerning natural philosophy until he immersed himself in the writings of Johannes Kepler in the summer of 1628. When he read Kepler's ideas about the movement of the Moon around the Earth, as put forward in his *Astronomia nova*, he wrote:

> Earlier I have written things about the motions of the stars and the Earth that are slightly different from his – that is, Kepler's – ideas and perhaps, when I get some free time and am set free from this very heavy load, unsuited for all thinking [he means his position as the head of the Latin school in Dordrecht], I will treat these matters much more accurately than he does, on the one hand because I start from the fundamental insight, which he refuses to acknowledge, that light, as I said before, is corporeal, and on the other hand, because he does not know what is very true, that is: everything that is moved, will continue to move unless it is hindered.[35]

A few months later, during the fall of 1628, so possibly just at the time Descartes renewed his friendship with Beeckman, Beeckman wrote:

> These things that Kepler writes about the motion of Mars, in terms of physics, please me very much, especially because long before I read those things I had thought of these same things and had the intention of using them for a reconstitution of astronomy (*restitutio astronomiae*). This can be seen in many places in this book [the *Journal*], especially

> where I discussed the motion of the Earth in a physical way. Now that Kepler has earned this glory before me, I hope that once I will be able to finish a work about this subject on the basis of my meditations, which he [Kepler] has not seen.[36]

When Descartes read or remembered these speculations, he knew that Beeckman meant what he said. Originally the *Journal* consisted only of loose exercise books, but by July 1628 Beeckman had had it bound in calf, thereby expressing his growing self-confidence and the pride he took in what he had discovered in natural philosophy.[37] And Beeckman did not leave it at that. We have strong evidence that just about that time he also began to collect the most important notes from his *Journal* and set them apart for a separate publication of his natural philosophy.

As is well known, during his lifetime no such publication materialized. When he died in 1637, however, his papers were entrusted to his younger brother Abraham, who in 1644 published a selection of Beeckman's notes in the *Mathematico-physicarum meditationum, quaestionum, solutionum centuria* (Utrecht 1644).[38] Abraham Beeckman said that he had made the selection himself, but there is reason to doubt this assertion. Cornelis de Waard, in his edition of the *Journal*, has carefully indicated which notes were published in the *Centuria*. If one pays attention to the dates of these notes, one will discover that there are no notes in the *Centuria* after 1629. The last of the notes put aside for publication in the *Centuria* is a report of Gassendi's visit to Beeckman in July 1629. Since the *Journal* does not end in 1629 but continues far into the 1630s, it is highly improbable that Abraham Beeckman himself made this selection from the *Journal*. Otherwise he certainly would have used some of Beeckman's notes from the early 1630s, when he had some interesting discussions with Mersenne, as well as Descartes. It is much more likely that Beeckman himself made the selection in 1629 or 1630, that for one reason or another he stopped doing so in 1630, and that after his death Abraham Beeckman published this selection without any further comment.

By now we have some idea why Beeckman stopped making a selection of his notes and working up his ideas into a more or less systematic treatise. The intimidating letters of Descartes must have discouraged him and made him decide not to pursue his old plans any further. Publication of his natural philosophy would only have landed him into a priority dispute with Descartes and he shied away from this prospect. As his brother Abraham noted in the *Journal* after Beeckman's death, the little man had had a gentle and amiable personality, avoiding disputes and discord as much as possible. After 1630, therefore, we no longer come across notes in which Beeckman speculates about what he might do with his insights. Instead of working on a book, in the early 1630s he spent more and more time in learning the difficult craft of grinding lenses. He continued with his research in much the same way as he did before his clash with

Descartes, and even a few days before his death – from tuberculosis – in May 1637, he still had the energy to carry out some astronomical observations, but this research remained a purely private affair. Beeckman by that time had no inclination whatsoever to share his views with the outside world by publishing them in a book. In this respect, Descartes had achieved his end.

But not completely so. Although the extent of Descartes' indebtedness to Beeckman only became clear after De Waard's discovery and edition of Beeckman's *Journal* in the first half of the twentieth century, it did not go completely unnoticed in the seventeenth century. When, in 1644, Abraham Beeckman at last published the *Centuria*, some people noticed the remarkable similarities in Beeckman's and Descartes' philosophies of nature. In the year of its publication, a Reformed minister and antiquarian from Nijmegen, John Smith, read the *Centuria* and he reported on it in a letter to Constantijn Huygens. He writes:

> In Zutphen, I recently have read, thanks to your kindness, Descartes' remarks on the magnet, but afterwards I read the *Centuria Meditationum mathematico-physicarum* by the Dordrecht rector Isaac Beeckman (already written in 1628, but published only recently), in which, under the numbers 36, 77 and 83 he shows that these [magnetic] corpuscles were not first thought of by Descartes.[39]

At least some of Descartes' contemporaries spotted his indebtedness to Beeckman.

Notes

1 AT i. 375.
2 Much of the content of this article is based on my PhD thesis, 'Isaac Beeckman (1588–1637) and the mechanization of the world picture', which was originally published in Dutch (Amsterdam, 1983) but which – in an English translation by Maarten Ultee – will soon be published by Johns Hopkins University Press. I have also profited from some recent studies on Descartes: William R. Shea, *The Magic of Numbers and Motion. The Scientific Career of René Descartes* (Canton, 1991); Geneviève Rodis-Lewis, *Descartes. Biographie* (Paris, 1995); Stephen Gaukroger, *Descartes. An Intellectual Biography* (Oxford, 1995).
3 Alexandre Koyré, *Galilean Studies* (Hassocks, 1978), 117.
4 E. Souriau, *L'instauration philosophique* (Paris, 1939), 58 n. 1, as cited in: A. Tillmann, *L'itineraire du jeune Descartes* (Paris, 1976), 903.
5 Descartes to Beeckman, 23 April 1619. *Journal tenu par Isaac Beeckman de 1604, publié avec une introduction et des notes par C. de Waard* (4 vols., The Hague, 1939–53), iv. 62. For convenience sake, I have cited the *Journal* wherever possible.
6 *Journal*, i. 244.
7 Rodis-Lewis, *Descartes*, 51, 131.
8 *Journal*, ii. 377.
9 Gaukroger, *Descartes*, 223.

10 Rodis-Lewis, *Descartes*, 52.
11 *Journal*, iii. 95.
12 Shea, *The Magic of Numbers and Motion*, 129.
13 *Journal*, iii. 95, 109; iv. 135–9.
14 *Journal*, iii. 112, 114.
15 *Journal*, iv. 148.
16 *Journal*, iv. 133.
17 *Journal*, iv. 133.
18 *Journal*, iv. 142.
19 *Journal*, iv. 163.
20 *Journal*, iv. 194.
21 *Journal*, iv. 171.
22 *Journal*, iv. 179.
23 *Journal*, i. 200–1.
24 *Journal*, iv. 191–2, 195.
25 *Journal*, iv. 192.
26 *Journal*, iv. 194–5.
27 *Journal*, iv. 195.
28 *Journal*, iv. 195–202.
29 *Journal*, iv. 198.
30 *Journal*, iv. 205–7.
31 Rodis-Lewis, *Descartes*, 128–9.
32 A. Gabbey, 'Les trois genres de découvertes selon Descartes', *Actes du XIIe Congrès International d'Histoire des Sciences, Paris 1968* (Paris, 1970) ii. 45–9.
33 Gaukroger, *Descartes*, 24. He refers to H. Floris Cohen, *Quantifying music. The Science of Music at the First Stage of the Scientific Revolution, 1580–1650* (Dordrecht 1984), 196.
34 Gaukroger, *Descartes*, 227.
35 *Journal*, iii. 74.
36 *Journal*, iii. 103.
37 *Journal*, i. xxviii; iii. 63.
38 De Waard knew of only one copy of this rare book in the University Library of Leiden. Recently, however, two more copies were discovered in the University Library of Bonn and the City Library of Lübeck. See H.H. Kubbinga, 'Nova Beeckmaniana', *De Zeventiende Eeuw* vol. 9 (1993) 82–3.
39 J.A. Worp, ed., *De briefwisseling van Constantijn Huygens*, IV (The Hague, 1915), 47.

3 The foundational role of hydrostatics and statics in Descartes' natural philosophy

Stephen Gaukroger

Introduction

The discipline of mechanics has traditionally been thought of as comprising three areas: statics deals with bodies in a state of equilibrium, kinematics with moving bodies, and dynamics deals with the forces responsible for motion. The ultimate prize of seventeenth-century physical theory was the last. Statics dealt with forces but not with motion; kinematics, on the other hand, dealt with motion but not with forces. Dynamics had to deal with both. Broadly speaking, this suggests two routes to dynamics. The first route is via statics. Since statics does not deal with moving bodies, but does deal with forces, the aim is to extrapolate the treatment of forces used to describe stationary bodies into the realm of moving bodies, e.g. by asking how these forces are modified or supplemented when the stationary body begins to move in a particular way. The advantage of this approach was that statics had been pursued since Archimedes in a precise, quantitative, geometrical fashion, which was exactly how seventeenth-century natural philosophers wished to pursue dynamics. The second route is via kinematics. Kinematics does not deal with forces but, at least from Galileo's *Two New Sciences* (1638) onwards, it does provide a precise, quantitative, geometrical account of motion, and for those who pursued this route to dynamics, the thought was that the kinematic analysis and classification of motions into various categories might yield the fundamental kinds of motion and rest, so that one could then associate different forces with these different fundamental states, and thereby explain what made them different.

Descartes, I shall argue, followed the first of these routes. But the situation is complicated by the fact that the two routes cannot be separated quite so easily, in spite of the fact that they lead in very different directions. Both Galileo and Descartes, for example, used models derived from hydrostatics, as well as more familiar ones from kinematics, in their work in physical theory. Galileo started with a hydrostatic model in his early work, and then abandoned it when he began to develop a kinematic model. The case of Descartes is more complex, for he operates with both models simultaneously, as if they were part of the same enterprise: more specifically, he tends to use statics to provide the forces by which to fill out kinematics. This generates anomalies, and I want to begin by drawing attention to two such anomalies, which should alert us to just how serious and deep the problems are, and which I shall argue can be accounted for once the role of his static model is appreciated.

The two anomalies are of rather different kinds, although they both appear to arise in the context of kinematics. The first occurs in Descartes' account of the inertial element in circular motions, where he seems to straightforwardly contradict himself: he argues that the only kind of inertial motion is rectilinear, and then goes on to assume what appears to be a form of circular inertia. The second occurs in his laws of collision, where he tells us that a smaller moving body in collision with a larger stationary one will never move the larger one, something that directly contradicts our empirical intuitions about what occurs, and which has no obvious kinematic rationale.

The principle of rectilinear inertia tells us, minimally,[1] that in the absence of external forces a body will continue in a state of rest or uniform rectilinear motion, and that these are the only two inertial states of a body. The argument is set out in the third law of motion, in ch. 7 of *Le Monde*, where Descartes argues that, since a body's tendency to move is instantaneous, this tendency to move can only be rectilinear, because only rectilinear motion can be determined in an instant. As he puts it, 'only motion in a straight line is entirely simple and has a nature which may be grasped completely in an instant,' and he goes on to explicitly rule out circular inertia, since circular motion would require us to consider 'at least two of its instants, or rather two of its parts, and the relation between them'.[2] Yet Descartes is also apparently committed to the existence of circular inertia. Indeed, strictly speaking, as we shall see, he is committed to two kinds of circular inertia – the orbital inertia of a stone in a sling, and the rotational inertia of a rotating light corpuscle – although rotation and orbital motion amount to the same thing for most purposes in a plenum.

The first problem arises in ch. 13 of *Le Monde*, where Descartes is considering what causes a stone moved in a sling to pull on the string[3] (see Figure 3.1). He argues that the tendency of the stone to move at a tangent [ACG] to the circular path it is following is to be analyzed in terms of two components of this tendency. One is a radial tendency outwards (centrifugal force) [DAE], the other is the motion along the circular path [ABF] which, we are told, is in no way impeded by the sling. In other words, the circular motion of the stone in the sling is not caused by any external constraint, including anything imposed by the sling: the body naturally follows this path. And in kinematic terms, this indicates that this circular motion is an inertial motion. The second case arises in a letter to Ciermans (23 March 1638). Ciermans had wondered why light rays are not retarded as they travel from the Sun to the Earth, and Descartes replies by

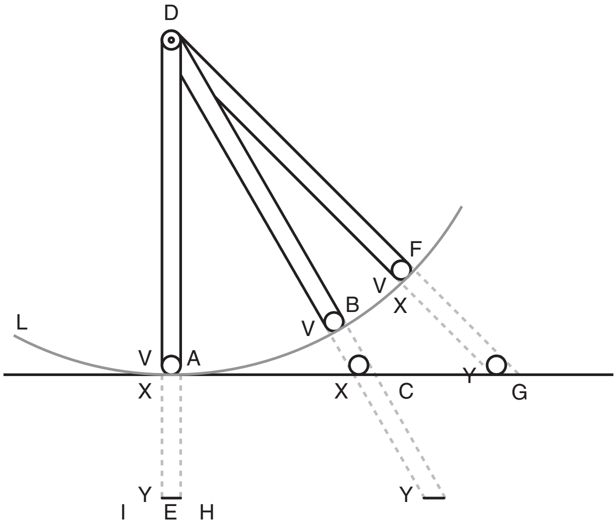

Figure 3.1

maintaining that light corpuscles would no more lose their speed than they would their rotational velocity. In the *Météors*, Descartes had given an account of production of colours whereby light corpuscles can acquire a rotational velocity, which is responsible for colour. Descartes writes: 'I don't know why you think the corpuscles of celestial matter do not maintain the rotation that gives rise to colours as well as the rectilinear motion in which light consists, for we can grasp both equally well by our reasoning'.[4] In other words, the rotation of light corpuscles needs no external force for its maintenance, any more than uniform rectilinear motion does: it is, in this sense, inertial.[5]

The second anomaly occurs in Rule 4 of the Rules for collision,[6] which specifies that a smaller body can never move a larger one, no matter what its velocity, and no matter how slight the difference in size. This is a very peculiar stipulation, and in no way follows from the other Rules: a smaller body moving a larger one in some circumstances is quite compatible with the other Rules.[7] And it is quite contrary to our empirical experience (to the extent that we can extrapolate to the case of perfectly inelastic bodies, which is what Descartes is concerned with) that a rapidly moving body A which was very marginally smaller than a stationary body B, would simply rebound on impact with B, having failed to affect B at all, and leaving it in the same stationary state as it was before impact.

I want to suggest that these 'anomalies', as I have called them, are not simply oversights, nor simply misunderstandings, on Descartes' part: they are surface manifestations of a deep structural ambiguity in his account. This structural ambiguity arises, I shall argue, because Descartes models his kinematics on statics, and particularly on hydrostatics. It looks as if the results are being delivered by kinematics, but in fact they are being delivered to a large extent by statics, and these are two very different ways of thinking through physical problems. At the most fundamental level, they direct attention to very different kinds of issue: they pick out very different things as requiring explanation. Elements of one way of thinking through physical problems, based on statics, which is the predominant model, come into conflict with elements generated by quite a different way of thinking through the problems. This arises, for example, where the kinematics that Descartes needs to resolve a question, and the statical concepts in terms of which he tries to pursue the resolution, are in conflict, so that when he should be thinking (kinematically) in terms of inertia he is in fact thinking (statically) in terms of equilibrium, and when he should be thinking (kinematically) in terms of how unequal bodies behave when they collide, he is actually thinking (statically) in terms of how unequal bodies behave when they are placed on a balance. I say 'should be' thinking kinematically, but the situation is unfortunately not so simple. In fact, as I shall show, by using a static model, he is able to produce novel, plausible, and far-reaching results that he could not have achieved had he tried – *pace* Galileo – to pursue his programme via a kinematics wholly independent of statics.

Galileo's hydrostatic model of free fall

We have a number of well-formed assumptions about kinematics, which derive from the role it plays in a tradition of thinking about physics in kinematic terms which effectively begins with Galileo and comes to fruition with Newton. In this tradition, kinematics is a discipline completely independent of statics, and it provides the backbone for dynamics. In order to understand the peculiarity of Descartes' approach, some outline of the kinematic approach would therefore be helpful. I have chosen Galileo for this purpose above all because Galileo moves decisively from statics to an independent kinematics, and the contrast with Descartes is all the sharper because of this.

Galileo started out in his early work with a hydrostatic model. Using this model, he had tried to account for the dynamics of free fall: that is, he had tried to identify and account for the forces operative in free fall. Hydrostatics dealt with forces, and seemed the key to dynamics, which also dealt with forces, but Galileo, no matter how hard he tried, was unable to transform the one into the other, and in his later work he turned instead to kinematics. Kinematics was very much a second best for him, for it made no reference to forces at all, although it turned out, in Newton's work, to provide the basis for dynamics.

Why did Galileo believe, in his early works, that hydrostatics held the key to dynamics? The hydrostatic model is developed most fully in his early account of free fall in the *De Motu* (c. 1590), where he takes issue with the Aristotelian account of projectile motion, whereby the continued motion of a projectile, once it has left the body (the cannon, or the hand, or whatever) that has projected it, is due to the surrounding medium. This account had notorious difficulties, and during the sixteenth century, it was replaced by *impetus* theory. On *impetus* theory, when a projectile is launched, the launcher imparts a force to it, which is 'impressed' on the body. While remaining an external force in the sense that it originates outside the body, it is effectively internalised by that body. When the body is projected upwards, the *impetus* gradually dies down – simplifying the process can be thought of by analogy with the gradual burning up of fuel by the body – and the body's motion gets slower and slower until, at the summit of its rise, it stops. Why does the body not then remain suspended in the air? The answer is to be found in the balance between *impetus* and the body's natural tendency downwards. The body's natural tendency downwards has remained constant while the *impetus* that drives it upwards has been diminishing (as it was gradually 'used up'). As the latter diminishes in relation to the former, the body will decelerate, and a point will be reached at which *impetus* and force downwards exactly balance (the apogee of the motion), after which the force downwards will predominate, and as the *impetus* gradually dies out, the body will accelerate, until finally a point will come at which there is no *impetus* left and the body will cease accelerating. It is this kind of picture that Galileo takes over as his model.

Two features of the *impetus* account are important for Galileo's purposes: it is dynamic and it has a quantitative element. *Impetus* theory invoked three forces to account for projectile motion: an external force by which the body is projected in the first place; the internalized version of this external force, *impetus*, which gradually runs out; and an internal force, conceived teleologically as something which enables the body to realise a natural goal, by which the body returns to its natural place. In building on *impetus* theory, Galileo retains its dynamic aspects: he is concerned to explain motion in terms of the forces responsible for it. As regards the quantitative question, *impetus* theory is quite different from Aristotle's own account. Aristotle introduces quantitative questions only in passing, in the context of a demonstration of the impossibility of motion in a void,[8] and he makes speed of fall directly proportional to absolute weight and inversely proportional to the density of the medium. The latter is designed to show, *per impossibile*, that bodies would move at an infinite speed in a void, because a void has zero density. *Impetus* theory, on the other hand, offers an explanation of variations in the rate of upward and downward motion of a projectile in terms of the net balance of forces acting on or in the body.

Galileo strips *impetus* theory down to bare essentials and rebuilds it, strengthening its quantitative aspects by applying the principles of hydrostatics, and in the process undermining its rationale in Aristotelian dynamics by relativising the notion of weight and effectively removing any role for the doctrine of natural place. He rejects Aristotle's theory that speed of fall is directly proportional to absolute weight by citing the example of two bodies of different weights which, when dropped from a tower simultaneously, reach the ground simultaneously; and he is able to show that the claim that speed of fall is inversely proportional to the density of the medium cannot hold, for cork, which falls at a particular rate in air, will not fall at a proportionately slower rate in water, which is denser, but will rise. Now one serious failing of the Aristotelian account of fall from the quantitative point of view is that it considers the matter in terms of incommensurable quantities: it makes rate of fall directly proportional to the *absolute* weight of the body and inversely proportional to the density or *specific* weight of the medium. We can make these quantities commensurable either by comparing the absolute weight of the body and the absolute weight of the medium, or by comparing their respective specific weights. The first is obviously not possible, as we do not know how much medium we would have to consider. The second is completely viable, however, and clearly overcomes the problems with Aristotle's account. If rate of fall is directly proportional to the specific weight of the body then it is clear why two lead balls of different absolute weights will fall at the same rate. And if it is inversely proportional to the specific weight of the medium, then whether a body will rise or fall in a medium depends on whether its specific (not its absolute) weight is greater than or less than that of the medium, which explains why a material such as cork or wood which has a higher specific weight than air but a lower specific weight than water will fall in air but rise in water.

What Galileo is doing here is trying to model the problem of free fall on statics. Archimedes had a well developed static account of why bodies rise in relatively dense fluids which worked in terms of comparing the specific weight of the body with the specific weight of the fluid. Galileo's idea was to argue that the fall of relatively dense bodies in air was effectively the same kind of problem, and that specific weight provided the key to the answer. In *De Motu* Galileo thought the key to the problem was to treat heavy bodies falling in air on a par with light bodies rising in water. The advantage of this is that techniques from statics and hydrostatics can be applied directly to the present problem. Statics and hydrostatics had been concerned with the conditions under which a body in a medium will rise or fall, where these conditions are conceived in terms of departure from an equilibrium state. Galileo attempts to generalise this analysis to cover the dynamical problem of the cause of differences in speeds of bodies moving through different media, and in doing so to render the dynamic problem amenable to the same kinds of geometrical treatment as a static one.

His approach is to equate, as mathematically identical, the buoyant effect of the medium and the artificial lightness that an impressed force induces in a body. When a body is thrown upwards a force is impressed on it which endows the body with an artificial lightness: this is an effect which alters the effective weight of the body immersed in the medium. Weight is relativised to effective weight, which is equal to the specific weight of the body minus the specific weight of the medium: when the effective weight takes a positive value the body will fall, when it takes a negative one, the body will rise.

Note two features of this account (features that will recur in Descartes). First, the move to a functional understanding of weight. Galileo still recognises some distinction between downward and upward motion: the former, being a natural motion and hence having a definite goal, needs only an intrinsic cause, whereas the latter, being violent and having no aim, must always have an extrinsic cause. But his account also undermines this distinction, for it is now quite unclear in what sense the upward motion of a cork in water is any less 'natural' than its fall in air. And more importantly, we cannot ask what causes a particular downward motion in a particular case unless we know something about the medium, namely, how its specific weight compares with that of the body. It is equilibrium, rather than natural place, that is now doing the real explanatory work. This brings us to the second feature, which is that the explanation of the cause of motion is given in terms of deviation from an equilibrium state. Bodies will neither fall nor rise if they are in a state of equilibrium with the medium in which they are immersed, and when they do move, the factor that determines their motion will be, not the absolute weight of the body or that of the medium, nor the specific weight of the body or the specific weight of the medium, but the specific weight of the body minus the specific weight of the medium: just as, when two bodies are in equilibrium on the arms of a beam balance, and when we break this equilibrium by adding some further material to one of the bodies, the resulting motion of the arms of balance is not a function of the weights of the bodies but only of the difference in their weights.

There is a sense in which the medium is constitutive of the problem here for Galileo. That is to say, Galileo has reformulated the question of free fall so that the medium is an essential ingredient in any well-formulated question about free fall: free fall is essentially something that takes place in a medium, and the question of the nature of free fall cannot even be posed unless we ask about the contribution of the medium. To understand why, consider the beam balance case. If two bodies are not in equilibrium on a balance, then we can say that their effective weights differ, but their absolute weights are irrelevant. If the bodies are initially in equilibrium, there are several things we can do to disturb the equilibrium. We can add something to one of the pans so that it moves down and the other pan moves upward. Or we can leave the contents of the pans as they were and move the beam to the left, thereby shortening one arm and lengthening the other. The lengthening of the left arm would result in an increase in the effective weight of the contents of the left-hand pan just as much as adding more material to that pan would have. And a similar result could be achieved by leaving the contents of the pans the same, and keeping the arms the same length, but immersing the right-hand pan in water. Effective weight is what matters, and this is a function of a number of factors. When we move to the case of bodies freely suspended in media, nothing changes: it is the effective weight that determines the direction and rate of motion.

The ideas of equilibrium and a functional understanding of weight are the key to the attempt to construe free fall in terms of statics and hydrostatics. As we shall see, they also play a crucial role in Descartes' attempt to think through circular orbital motion in terms derived from hydrostatics. Galileo's and Descartes' accounts are very similar in many respects. Both try to provide a dynamic account of motion by means of hydrostatics, because they both see this as the route to a mathematical account of motion. Because their model is equilibrium in fluids, they both think of motion primarily in terms of the contribution of the medium to the motion of the body, and both try to think through the problem of force in terms of a balance or lack of balance between the moving body and the medium.

Galileo's move to kinematics

The account of motion in *De Motu* is dynamic, invoking the forces responsible for motion and trying to give an account of these in terms derived from hydrostatics. After *De Motu*, Galileo abandoned the hydrostatic approach to dynamics and it never again acted as a model for his dynamics. He was never able to provide a viable dynamic theory, and in his most basic mature treatment of the nature of motion, the *Two New Sciences*, he eschews dynamics altogether: where forces enter the picture they enter it as the resultants of motion – e.g. the friction caused by a body moving through a resisting medium – rather than the causes of motion. His treatment of motion is purely kinematic, that is, it attempts to provide a quantitative description of motion, nothing else.

There are a number of reasons for this shift from a hydrostatically modelled dynamics to a kinematics, and Galileo gradually realised that his hydrostatic account in the *De Motu* could not work.[9] In the *De Motu*, he had argued that the solution lay in substituting specific weight for absolute weight, maintaining that the rate of fall of a body is directly proportional to its specific weight and inversely proportional to the specific weight of the medium through which it travels. But it gradually became evident that things were not so simple. If the proportionality were as *De Motu* maintains, we would expect the proportions at which two bodies of different specific weights fall in one medium to be reflected in their rates of fall in a different medium. But as Galileo discovered, this does not happen.

What Galileo comes up with in the *Two New Sciences* is a completely different kind of explanation of free fall and projectile motion from the one he had offered in *De Motu*. Motion is not analysed in terms of a balance of forces, but in terms of components into which the motion can be resolved, and the most fundamental component in the case of a freely falling body is its uniformly accelerated motion, because this is the only universal component in free fall. His starting point is now the fall of a body in a void, that is, in the complete absence of a medium. In other words, the medium is now no longer constitutive of the physical problem: it is not seen as something that facilitates or causes motion in some cases (such as the upward motion of a light body in a relatively dense fluid), impeding it in others (the slow fall of a heavy body in a dense medium). Rather, it is seen exclusively in terms of the resistance it offers to motion.

Galileo's later kinematics conflicted with his early hydrostatically modelled dynamics because the two models picked out completely different features of the physical situation as being significant. Both tried to deal with the problem of the behaviour of a body falling in a medium by construing it in terms of a more fundamental or general case where the underlying physical issues could be identified and analyzed more clearly. The hydrostatic model led to the situation being generalized to the motion of bodies in fluids, whether this motion was upward or downward. The kinematic model led to the search for a component of motion that was common to all cases of free fall, and then an examination of how the action of this component was modified with the addition of other variables. The role of the medium was part of the condition of the problem in the first case. But in the second case, it was explicitly absent: what is identified there as holding the key to the understanding of free fall is the case where the basic physical features of the situation are to be explored by asking how a body behaves in an inert empty space.

Galileo's kinematics turned out to be the key to dynamics in the seventeenth century. Although Galileo himself never thought of it in these terms, what it provided was a mathematically precise skeleton, as it were, which dynamics was to flesh out with forces. It was Newton who realised that kinematics identified and quantified the basic physical processes, and he realised that what dynamics had to do was to take these suitably identified and quantified processes, and associate the requisite kinds of force or inertial state with them. Newton's *Principia* provided a spectacular vindication of this use of kinematics. It was kinematics, not hydrostatics, that was the path to dynamics, because static forces were not like dynamic ones, and the attempt to extrapolate from hydrostatics to dynamics would not work. Indeed no direct approach was possible: kinematics was needed to identify and quantify the relevant physical states and processes, so that dynamics, once (and only once) these states and processes had been identified, could then set out what kind of causal process, if any, was responsible for them.[10]

Descartes' hydrostatic model in cosmology

Descartes' approach to questions of force and continued motion is very different from the Galileo/Newton model. That there is something peculiar going on, something that jams his kinematics, as it were, is clear from what I labelled above the two 'anomalies' in his cosmology and collision rules, and I now want to examine just what this is.

I will turn first to his hydrostatic model in cosmology, initially developed in *Le Monde*. This was the dominant physical model of the solar system in the mid-seventeenth century, offering a far more attractive picture, to mechanists, of how a heliostatic system might function, than anything in the versions of Galileo or Kepler, both of which require action at a distance. In this account, physical effects are produced by means of vortical motions in an all-encompassing fluid (see Figure 3.2). One of the aims of the model was to account for the stability of planetary orbits, and this is achieved in a way that invokes no 'occult' forces, such as gravity,

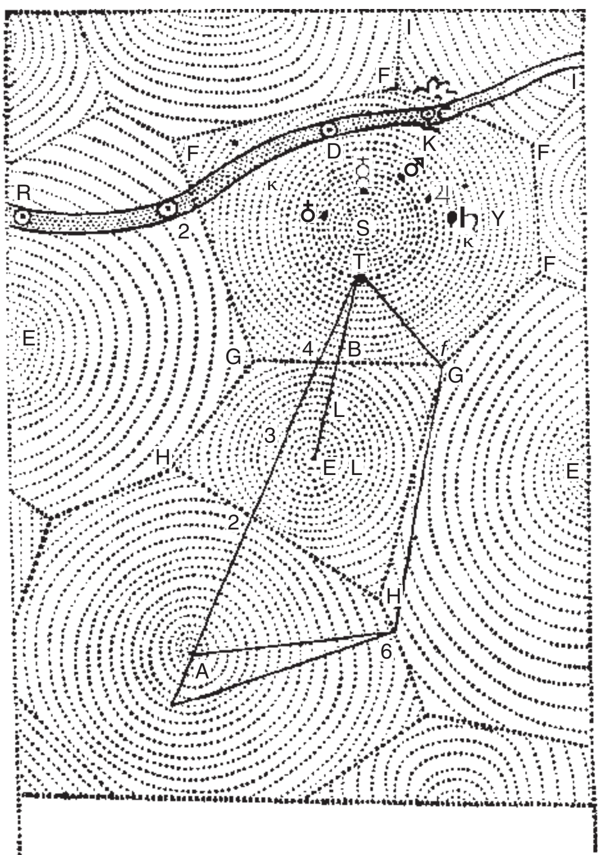

Figure 3.2

because it acts by contact between the bodies affected. We must imagine the universe to be a spatially extended region which is wholly occupied by matter – what we can call material extension. The constituent matter has an initial motion (provided by God) and as a result of this motion it breaks up into large pieces of matter (planets), middle-sized pieces (liquid and gaseous matter including the atmosphere and interplanetary ether), and small, effectively formless, matter filling up the interstices between the other parts of matter and making up light and heat. If one allows rotation of various parts of this material extension, which form individual solar systems, then Descartes believes that all he needs to establish the rotation of the planets around the sun are his theory of matter, centrifugal force, and rectilinear inertia. In such a system, he argues, the large parts of matter will be flung outwards and the small matter will be pressed into the centre. The large clumps of matter will be arranged according to their size, the larger being the further out, because larger bodies will be able to realise their tendency to follow a rectilinear path more effectively, and so will describe a larger circle, which more closely approximates to a straight line, than smaller parts of matter. This will result in an ordering of large bodies in the solar system which matches the ordering of the known planets and what he takes as their estimated sizes: Mercury, closest to the Sun, then Venus, Earth, Mars, Jupiter, and finally Saturn. The planets are swept along circular paths in and by the dense fluid that fills the interplanetary spaces; their orbits are stable because if a planet were to move closer to the Sun it would encounter more rapidly moving matter and would be squeezed back, whereas if it moved away from the Sun it would meet larger pieces of matter moving more slowly, which would retard its motion and cause it to fall back into its original orbit. Moreover, the smallest matter is squeezed into the centre where it rotates rapidly. This central region, which we call the Sun, radiates fine matter in all directions because of the centrifugal forces at its surface. This is how light is propagated throughout the solar system.

This account is subject to some profound difficulties. Size and density are used interchangeably in *Le Monde*, for example, where the distance of planets from the Sun seems to be a function of their size (which has the consequence of making Saturn larger than Jupiter[11]), whereas the stability of their orbits at particular distances from the Sun is explained in terms of their density.[12] Nevertheless, Descartes' account does provide an attractive general picture of the stability of planetary orbits, and he builds on his account to explain such recalcitrant phenomena as the moon's orbit around the Earth and the tides. It provided an intuitively plausible theory, and one open to quite sophisticated elaboration. Descartes himself never claimed that planetary orbits would be exactly circular,[13] and once the elliptical nature of planetary orbits had been accepted and taken seriously, for example, many Cartesians tried to show how vortices could generate elliptical orbits; indeed, in 1730 Jean Bernoulli won the prize of the

Académie des Sciences for a derivation of Kepler's third law from the vortex theory. And Fontenelle was defending it as late as his *Théorie des tourbillons* of 1752.[14] Still, it cannot be denied that the fortunes of vortex theory eclipsed radically with the publication of Newton's *Principia*.

In particular, in Book III, Newton showed that in a Cartesian vortex, where the density of the medium is the same as the density of a body moving in it, the body would lose half its motion before it travelled a distance equal to twice its diameter. Now this latter criticism reflects a fundamental difference between the ways in which Descartes and Newton pursue physical enquiry. Newton looks at the fluid through which a body would travel in terms of the resistance a surrounding medium offers to the body's motion. Descartes, on the other hand, thinks of the fluid as being what carries the body along: resistance just does not seem to come into it. This difference derives from a difference in physical models for dynamics. Newton has a kinematic model, Descartes a hydrostatic one. Cartesian physics is generally seen as a precursor of Newtonian physics, as something that engages in essentially the same project as Newton but with a considerably lesser degree of success. But if we are trying to understand Descartes' project in its own terms, without building in any assumptions about continuity with Newton, then we can make more sense of what he is trying to achieve, and we can resolve some apparent anomalies in the role of kinematics in Descartes' physical theory which the Newton-centred account cannot explain.

Descartes uses a hydrostatic model, rather than a kinematic one, in his exploration of cosmological questions because hydrostatics deals with forces, whereas kinematics does not, and what he wants is an account of force. Moreover, whereas the analytical application of the notion of equilibrium is somewhat counter-intuitive in the case of bodies undergoing free fall – the case to which Galileo tried to apply it – it does have a clear intuitive appeal as an analytical notion in the case of a body in a stable circular orbit. We can think, as Descartes does, of a body being held in a stable orbit in terms of forces that act outwards from the centre being exactly balanced by forces that act inwards from the periphery, and the notion of equilibrium seems quite appropriate here. The trouble is that this hydrostatic model directly contradicts what has seemed, with the 'benefit' of hindsight, to be a crucial kinematic result, namely the principle of rectilinear inertia. His hydrostatic model leads him to accept a notion of what is effectively circular equilibrium. It is crucial that we identify the different contributions of statics and kinematics to his account, if we are to understand just what is going on here. The principle of rectilinear inertia tells us that in the absence of 'external' forces a body will continue in a state of rest or uniform rectilinear motion.[15] The principle of circular equilibrium tells us that a body in circular motion is in a state of dynamic equilibrium, it is dynamically balanced, and in the absence of 'external' forces will continue in that state. This is a problematic principle – after all, there is a sense in which every body is dynamically balanced, as Newton's third law of motion indicates – but it is not the principle itself that generates the problems in Descartes' account. Rather, these problems arise from the fact that Descartes describes rectilinear motion and circular motion by reference to what turn out to be conflicting principles. But because these conflicting principles derive from different models, which draw attention to different aspects of the situation and pick out different things as requiring explanation, the conflict is not so apparent, at least to Descartes, who seems to move between equilibrium and inertia as if they were the same thing.

Descartes' static model in kinematics and optics

Descartes has a static notion of force underlying his cosmology, but, more surprisingly, he also seems to have a static notion of force underlying what might ordinarily be regarded as his kinematics. If anything can be identified as kinematics in Descartes it is surely his rules of collision, but the content of these rules does not seem to be guided kinematically. This can be illustrated by considering Rule 4 (*Principia*, II, art. 49), which is, by kinematic standards, a very peculiar rule.[16] It tells us that if a moving body collides with a 'larger' (more massive) stationary body, then the smaller body, no matter how slight the difference in size, and no matter how quickly it is moving, will never dislodge the larger one, but will rebound off it, its 'quantity of motion' being conserved.

I want to consider, first, the physical-cum-metaphysical rationale that Descartes offers for the law; second, what it is that this rationale 'rationalises', namely a statically modelled dynamic principle; and, third, why Descartes needs a rule stating that smaller bodies cannot move larger ones, namely, because his basic optical laws would not hold unless this were the case.

If one looks to Descartes for a rationale of the law, what one finds is a physical claim – that a smaller moving body colliding with a larger stationary one cannot affect the state of the larger body – filled out in quasi-scholastic natural-philosophical terms. There are two important premisses in Descartes' treatment. The first is that rest has as much reality as does motion: rest is not simply a 'privation' of motion as the Scholastics had argued. The second is that rest and motion are opposed to one another: they are modal contraries. We must therefore think of the interaction of the bodies in terms of the smaller having a particular quantity of motion, and the larger having a particular quantity of rest. These are opposing states, so the bodies will be in dynamic opposition, and Rule 4 therefore describes a contest, as it were, between a larger body at rest and a smaller body in motion. The bodies exercise a force to resist changes of their states, and the magnitude of this force Descartes considers to be a function of their size. A body in motion cannot, for that reason alone, have more force than one at rest; nor can greater speed confer greater force upon it. Either of these would undermine the ontological equivalence of rest and motion that Descartes wants to defend. Now, bearing this in mind, we can ask what happens when the smaller moving body collides with a larger stationary one. Clearly they cannot both remain in the same state in collision, so there will have to be a change of state. And since the smaller or 'weaker' body can hardly change the state of the larger or 'stronger' one, it is the smaller one that has its state changed (the direction of its motion is reversed), the larger body remaining unaffected in the process.

This account explains why it has to be an all-or-nothing matter. We might be tempted to ask why the smaller body should not move the larger one if the smaller body had sufficient speed, or if the difference in size were very marginal. The answer to the first question is that the speed of the smaller body is irrelevant to the outcome of the collision. The answer to the second is that, because of the irrelevance of speed, the only remaining factor is size. Still, it does seem somewhat peculiar that the outcome would be the same irrespective of whether the difference in size were very significant, or whether the bodies were almost exactly the same size. The peculiarity is removed immediately once we think of the situation in terms of statics, however. Think of the bodies as occupying the two pans of a beam balance. The arm will always be tipped down on the side of the heavier, no matter how slight the difference in weight.[17] That this is indeed the reasoning behind Descartes' account is made clear in a letter to Hobbes in which Descartes responds to Hobbes' claim that the extent to which a body is moved is proportional to the force exerted on it, so that even the smallest force will move a body to some extent. Descartes replies:

> His assumption that *what does not yield to the smallest force cannot be moved by any force at all* has no semblance of truth. Does anyone think that a weight of 100 pounds in a balance would yield to a weight of one pound placed in the other pan of the scale simply because it yields to a weight of 200 pounds.[18]

What Rule 4 seems to do is to reduce the question to one of statics, by removing considerations of speed. And the means by which it does this is through the principle of the ontological equivalence of motion and rest. Descartes' statement of this equivalence has often been seen as an important move in the direction of a proper understanding of the principle of inertia, as a step on the road from seeing rest simply as a privation of motion, to treating rest and uniform rectilinear motion as being dynamically on the same footing, as being states that require no force for their maintenance. This may well have been the route followed in Newton, and he may well have been directed along this route by reading Descartes.[19] But it is not so clear that this captures the direction of Descartes' own thinking. Quite the contrary, I suggest that the principle of the ontological equivalence of motion and rest, which in a physical context such as the rules of collision amounts to a dynamic equivalence, is in fact a step in a completely different direction for Descartes. The ontological/dynamic equivalence of motion and rest means that what holds for rest holds for motion. Statics tells us about the behaviour of bodies at rest: perhaps it can be built upon to deal with bodies in motion, if motion can somehow be seen to be a variation on rest. This was Galileo's approach in his early writings, as I have indicated, and it was an approach to dynamics with great appeal. Descartes does not abandon the conceptual apparatus of statics in his treatment of collision: on the contrary, he seems to be trying to build on it.

What is particularly striking is that the result embodied in Rule 4, that a smaller moving body can never move a larger stationary one, is that it is a crucial result for his optics, for it is there that Rule 4, despite its somewhat counterintuitive appeal, shows its mettle by paying off handsome dividends.

In the case of light, Descartes is concerned to explain why light rays, which follow rectilinear paths, behave in particular geometrically defined ways when they are reflected or refracted. And the kind of explanation he seeks is one which models light micro-mechanically, in which, in the case of reflection for example, light corpuscles strike a larger body and are reflected from its surface. Kinematically specified laws of collision, of the kind Descartes provides, should be enough to describe the various kinds of interaction possible here, and in this way should underpin an explanation of why light behaves in particular geometrically defined ways when it encounters a reflecting surface, or when it moves from one optical medium to another.

The linchpins of this treatment are his accounts of reflection and refraction. Take the case of reflection, as explained in the *Dioptrique* (see Figure 3.3). Descartes starts from the idea that when a light ray strikes a

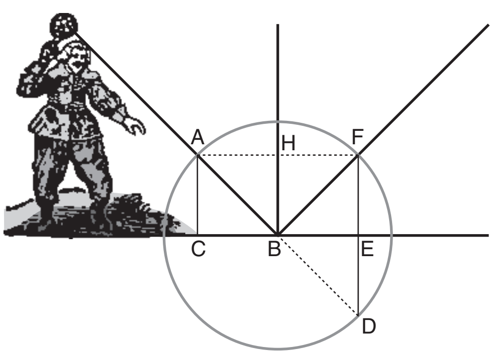

Figure 3.3

reflecting surface obliquely, the angle of incidence equals the angle of reflection. To show why this happens, he resolves the ray into components, and he distinguishes the speed of the ray and its direction. Using the model of an inelastic tennis ball striking a hard surface and being reflected, he points out that if the force of motion and direction of motion were the same thing, then the ball would first have to stop before it changed direction, and if it stopped a new cause would be needed for it to move again. But there is no such new cause available: therefore, its force is not affected in the impact, only the direction of its motion, which is changed. He then goes on to show how the 'determination to move' of the ball from its starting point [A] to the point at which it is reflected [B] can be resolved geometrically into motion along a vertical component [AC] and motion along a horizontal component [AHF]. And since the collision with the ground can only hinder the second of these, not the first, the first component continues to act uninterrupted. In other words, the power by which something moves and the power which determines its motion as being in one direction rather than another are different powers.

In fleshing out the geometry of the situation in physical terms, Descartes simply has to imagine the light ray being composed of minute corpuscles and striking a larger body. Now if such a body were to be moved by a light corpuscle, then of course the light corpuscle would have to transfer some of its motion to the larger body, in which case it would be retarded, and not only its direction but its speed would also be affected. And if this happened, the angle of reflection would not then equal the angle of incidence: rather, the situation would be more like refraction, where a change in the speed of the light ray causes the bending of the ray. The kinematics have got to match what we know about the geometry of reflection, and the geometry of reflection does not deal with approximations: geometrical optics is just a particular interpretation of geometry, which is the paradigm of exactness. In providing a physical model for the geometrical behaviour of light rays, this exactness, which is of the essence of geometry, cannot be lost. If the geometrical analysis of the behaviour of light shows that the angle of incidence equals the angle of reflection, it equals it exactly, whether the light is striking a raindrop or the ocean. And if that is the case, the light corpuscle cannot move the body from whose surface it is reflected.

For these reasons, it seems to me that statics is as central to Descartes' account of kinematics as hydrostatics is to his account of cosmology. And in both cases, they are able to deliver the goods: the stability of planetary orbits without recourse to occult forces on the one hand, and the physical grounding of geometrical optics on the other. Yet there can be no doubt that they also engender confusions, as the case of 'circular inertia' shows, and there is an inevitable strain in Descartes' physical theory as principles drawn from statics and hydrostatics are called upon to handle problems that are quite beyond the resources they offer. If I have correctly identified the source of the difficulties, then I believe we have a good understanding of just what the confusion consists in.

Newton's use of kinematics as a foundation for dynamics

It is a mistake to think that kinematics has a fixed or given role in seventeenth-century physical theory. For the mature Galileo it was primarily a theory about rectilinear motion and the rectilinear components of curved motions, which had no essential bearing on dynamic issues. For Descartes it was primarily a theory about how to describe the micro-corpuscular behaviour of light rays. For Newton it provided a mathematically precise skeleton, as it were, which dynamics was to flesh out with forces. I said earlier that kinematics, not hydrostatics, turned out to be the path to dynamics, because static forces were not like dynamic ones, and the attempt to extrapolate from hydrostatics to dynamics did not work. Indeed, no direct approach was possible: kinematics was needed to identify and quantify the relevant physical states and processes, so that dynamics could then set out what kind of causal process, if any, was responsible for them. But no one could have known this, or suspected it with any degree of certainty, before the event.

There is a tendency to assume that the kinematic route to dynamics is so clearly the right way to proceed that the choice of kinematics over statics was clear cut once Newton had established the former. But in fact there were advantages and disadvantages of the kinematic approach in relation to the static approach, and the situation was not so straightforward. As an example of an advantage, an interesting case is that where the hydrostatic model might look superior to the kinematic model, namely the motion of bodies carried through fluid media. Because Descartes' account was the dominant cosmological account in the mid-seventeenth century, Newton rightly felt that he had to undermine this account if his own was to accepted. This is why he devoted a whole Book of the *Principia* to this question. In Book I, Newton sets out his general principles of the dynamics of moving bodies, the laws of motion being presented as laws describing what happens in a void, and in Book III he applies the results of Book I to the motion of moons, planets, and comets. In the middle comes Book II, which appears somewhat anomalous, as it effectively breaks the continuity of the argument. But it is in Book II that the crucial work is done in showing why a hydrostatic account will not work. Book II examines the motion of bodies in fluids, the motion of fluids themselves, wave motion, and so on. In particular, it contains quite a detailed and devastating criticism of the vortex theory, which shows that unless there were a constant input of energy at their centres, the motion in Descartes' vortices would very quickly be evenly distributed. And in Book III, as I mentioned earlier, Newton showed that in a Cartesian vortex, where the density of the medium is the same as the density of a body moving in it, the body would lose half its motion before it travelled a distance equal to twice its diameter. The latter argument, in particular, shows the power of the kinematic model to undermine the hydrostatic one. The hydrostatic approach models fluids wrongly, whereas the kinematic model can provide a viable account. I say 'can' because Newton's account of fluids in Book II was actually rather problematic and had to be extensively reworked by Euler, but Euler's analysis[20] works with the Galileo/Newton kinematic model. Starting with a kinematic analysis of motion and moving to the dynamics of isolated mass-points, Euler proceeds to rigid bodies, which he builds up out of the mass points he had just analyzed, then considers flexible bodies as a dynamic modification of rigid bodies, then elastic bodies as a dynamic modification of flexible bodies, and finally fluids, as a dynamic modification of elastic bodies, developing his increasingly complex physical and mathematical tools as he goes on. This allows a far more sophisticated grasp of fluids than simply thinking of them as resistance. A kinematically based dynamics provides a far better account of the behaviour of fluids than does hydrostatics.

But the Galilean kinematic approach does have drawbacks from the point of view of dynamics. In particular, it opens up a gulf between gravitation and inertia because isolated bodies always have analytical priority in this model, and such an approach is of no use in modelling gravitation. From the point of view of inertial states, the shift from a one-body universe to a universe in which there are two bodies which collide with one another, for example, is relatively straightforward. But the shift from a one-body universe, in which we do not have to consider gravitation (assuming we can treat the body itself as a mass point in which there are no internal differential gravitational effects), to a two-body system, in which we do have to consider gravitation, is not so straightforward. The one-body universe tells us nothing about the two-body universe in this respect, and gravitation comes out as an added extra, which appears only when we have more than one body. The problem is that there is a universal numerical equality between the inertial mass of a body, which determines its acceleration under the action of a given force, and its gravitational mass, which determines the gravitational forces between it and other material bodies, suggesting, as Einstein pointed out, that there is an identity between the two. But we are prevented from exploring just what this relation is in classical mechanics because the Galilean kinematic model forces us to see inertia as being part of the material substance itself, whereas gravitation can only be seen in terms of the effect of this material substance in the space surrounding the body/mass point. Bodies just seem to have two fundamentally different properties: gravitation and inertia.

I am not suggesting here that a hydrostatic model is the way to unify gravitational and inertial mass. Nor am I suggesting that a theory that models the behaviour of bodies in terms of surrounding fluids is the same as a theory that models the behaviour of bodies in terms of surrounding fields. Fields and fluids are very different: the commitment of a mechanist like Descartes to fluids is motivated, at least in part, by the view that wherever there is physical influence there must be material contact, whereas the original point of introducing fields, by writers like Boscovich and Kant, was to show how there could be physical influence without material contact. Yet by the nineteenth century, fields and fluids do come together, and we can begin to see how a development of a hydrostatically modelled version of dynamics, were such a model viable, might have connected up with the development of field theory in an intuitively compelling way. In the 1850s, James Clerk Maxwell, pursuing the analogy between electricity and the flow of a fluid, set out to provide a comprehensive mathematical unification of electricity and magnetism. The physical model he used was that of electricity and magnetism being conveyed through the interactions of vortices spinning in a fluid – the ether – that completely filled all of the space between material objects. In a paper on the ether, he tells us that a medium, 'though homogeneous and continuous as regards its density, may be rendered heterogeneous by its motion, as in Sir W. Thomson's hypothesis of vortex-molecules in a perfect liquid. . . . The aether . . . is probably molecular, at least in this sense'.[21]

We cannot rule out the possibility of a hydrostatic route to dynamics, one in which the transition to field theory might be eased, and in which the disastrous separation between gravitation and inertia was wholly absent. But until the details of what form such a route might take are provided, and in the light of the grave problems that we have seen attend such an account in the seventeenth century, we must reserve judgement as to its viability. There is one lesson we can draw, however, independently of whether the hydrostatic route to dynamics is viable or not. The strength of the kinematic model in some respects does not mean it is strong in every respect, and it may not be the most useful model for all purposes in physical theory. Using different physical models may help us to identify problems that we might otherwise be hindered from seeing, and to envisage solutions that might otherwise escape us. Descartes' use of a hydrostatically modelled cosmology enables him to pose the question of the stability of planetary orbits within the constraints of contact action, and his use of a statically based kinematics enabled him to flesh out his account of the geometrical behaviour of light rays in physical terms. In both cases, he made remarkable progress not only in identifying some of the key problems, but in offering serious solutions to them. And he achieved this not despite his failure to grasp the independent kinematic basis of dynamics, but because of his failure to grasp this.[22]

Notes

1 I say 'minimally' because I do not want to raise here the thorny question of whether Descartes holds that the maintenance of an inertial state – taking this to be a state in which a body will continue in the absence of any external forces – is caused by an internal physical force (manifested in the body's resistance to changes to its inertial state), a supernatural force (due to God's recreating/renewing bodies in particular inertial states when he recreates/renews them at each instant), or no force at all.

2 AT xi. 45.

3 AT xi. 85–6.

4 AT ii. 74.

5 Descartes' insistence that light corpuscles conserve their rotational velocity does not seem to derive from optical considerations. If we were to allow that the rotational velocity of light corpuscles can be retarded, we would expect to see the colour of light rays change as they travelled greater distances. Descartes seems to assume that we do not experience this, but there is some case to be made that we do in fact experience a phenomenon like this. Distant objects tend to look blue, as the painters of the Renaissance realised. There is a blue shift, as it were. Without the assumption of rotational inertia, Descartes' account of colour production could provide a straightforward explanation for this: a retardation of the rotational velocity of the corpuscle would produce a blue shift because the slower rotations are correlated with the blue end of the spectrum. What motivates Descartes to think in terms of rotational inertia here does not seem to be anything to do with the basic optics of the situation.

6 *Principia*, Part II, art 49. AT viii-A. 68.

7 Except for Rule 7(b), which simply follows on from Rule 4.

8 *Physics*, $215^{a}24$–$216^{a}21$.

9 See Galileo, *Two New Sciences*, trans. Stillman Drake (Madison, 1974), 65–108, for Galileo's mature account of free fall. See also the discussion in Stephen Gaukroger, *Explanatory Structures* (Hassocks, 1978), ch. 6.

10 My interpretation here, while I think it is valid for the limited purposes of this paper, because it captures what is the main thrust of Newton's thought, would certainly require qualification if Newton were examined in more detail. I am thinking in particular of the extent to which Newton uses the notion of virtual velocity, a notion derived from statics. In the eighteenth century, we find two very different developments of Newtonian dynamics: that of D'Alembert, who wants to replace forces with accelerations, and makes great use of virtual velocities to this end, and Euler's attempt to base dynamics on kinematics, which was accepted over D'Alembert's account in the eighteenth and nineteenth centuries.

11 Tycho, who provided the most accurate observations before the introduction of the telescope, had estimated the volume of Saturn to be 22 times that of the Earth with a radius 31/11 times that of Earth, whereas the volume of Jupiter is calculated to be only 14 times greater and its radius only 12/5 times that of Earth. Once telescopic observation had established disc sizes it became clear that Jupiter was larger than Saturn. But Descartes, who took little interest in observational astronomy, may not have been familiar with the disc sizes. The situation is complicated by the fact that we cannot simply compare disc size and period to ascertain the size of a planet on Descartes' account. Planets closer to the Sun than Saturn have 'artificially' shortened periods because their motion is accelerated by the Sun's rotation, which drags the celestial fluid in which they are embedded around with it. But this has the effect of making Saturn's period appear shorter than it actually is, and hence making it appear

closer to us than it actually is, which means that we are inclined to underestimate its actual size.

12 The *Principia* go some way to overcoming this anomaly by making density the sole operative factor: see Part III art. 148, for example.

13 *Principia* III art. 30: 'We see that, although these whirlpools always attempt a circular motion, they practically never describe perfect circles, but sometimes become too great in width or in length [*French ed. adds*: so that all the parts of the circumference which they describe are not equidistant from the centre]. Thus we can easily imagine that all the same things happen to the Planets; and this is all we need to explain all their remaining phenomena.' Compare the title of art. 34: 'That the movements of the heavens are not perfectly circular'.

14 Fontenelle was 95 when he published his treatise, however, and it is likely that he had completed it earlier, perhaps much earlier.

15 I put scare quotes around 'external forces' because there is an element of indeterminateness in the issue of whether any internal forces – 'force of rest' and 'force of motion' – are present in bodies in inertial states, and what the physical standing of such forces might be. See footnote 1, above.

16 I am grateful to Peter McLaughlin for pointing out to me the central importance of statics in Rule 4 (developed in his ch. 4 of this volume), and to John Schuster for pointing out the consequences of Rule 4 for the law of reflection.

17 I am, of course, assuming an idealised frictionless balance.

18 Descartes to Mersenne for Hobbes, 21 January 1641, AT iii, 287.

19 See Alan Gabbey, 'Force and inertia in the Seventeenth Century: Descartes and Newton,' in S. Gaukroger, ed., *Descartes: Philosophy, Mathematics, and Physics* (Brighton, 1980), 267ff.

20 Leonhard Euler, *Theoria motus corporum solidorum seu rigidorum* (1765), in *Leonhardi Euleri opera omnia*, series 2, vols 3–4 (Berne, 1948). I discuss Euler's account in my 'The metaphysics of impenetrability: Euler's account of force', *British Journal for the History of Science*, vol 15 (1982), 132–54.

21 Cited in Mary Hesse, *Forces and Fields* (London, 1961), 207.

22 Research for this chapter was supported by a grant from the Australian Research Council. I am grateful to John Schuster for comments. I presented earlier versions at Federal University of Rio de Janeiro, Harvard, All Souls College, Oxford, University of Sydney, and University of Melbourne, and I am grateful to audiences for advice and comments.

4 Force, determination and impact[1]

Peter McLaughlin

The Cartesian universe consists of matter in motion. Introducing motion into extended substance (matter) divides it up into bodies, each with two primary modes that undifferentiated, undivided, and unlimited *res extensa* cannot have: shape and state of motion. Two contiguous parts of extended substance are only separated into distinct bodies by their relative motions; two contiguous parts are only joined in one body by their relative rest. Once in motion, bodies are constantly colliding with one another – in fact, collision is the only interaction they are capable of. The two primary modes of a body in turn have modes of their own: shapes have surfaces and motions have determinations. These are all *quantitative* concepts, and together with logic and Euclidean geometry they provide the basic conceptual tools that Descartes uses to construct a quantitative mechanistic physics. The deductive core of this physics, as presented in Part II of the *Principia Philosophiae,* is centred around the principle of the conservation of motion or force and three Laws of Nature that govern the behaviour of bodies. These laws describe how the *force* or motion of a body and the *determination* of this force regulate its behaviour in *impact* with other bodies.

In spite of considerable progress in recent years in understanding some of the darker corners of Descartes' conceptual scheme, there is still considerable uncertainty, often even in the best literature, on two important points: the precise relation of 'determination' to the force or motion it is supposed to determine and the way Descartes conceives of how force is actually involved in collision. At least some of this uncertainty seems to me to be unwarranted. I shall try to clarify both points by concentrating on Descartes' basic conceptualisation of force and its determination as this is embodied in the representations of these quantities.

Dealing with the first point will involve some rather complicated hermeneutics – including the assertion that Descartes himself at one point gets his own theory wrong. The second problem, on the other hand, will be comparatively smooth sailing, since it involves primarily simply taking Descartes at his word (or at his picture). In the following, after sketching the deductive core of Cartesian physics, I shall attempt first to explain the concept of determination and how it relates to motion, and then to analyze the role of both force and determination in Descartes explanation of impact.

1 The deductive core of Cartesian physics

The relation of Descartes' physics to his metaphysics has been debated by scholars for many years. Descartes himself tells us that his physics is derived from his metaphysics, and if the physics turn out to be false then his metaphysics too must be false. Historically, we know the physics came first and the metaphysics later, and we tend to think that Descartes attacked Aristotle in physics first and, as a flanking measure, developed an alternative to Aristotle's metaphysics as well. I shall not be dealing with the typical metaphysical questions here. But the 'meta'-level of physics is not confined just to *metaphysica specialis* – questions of God, freedom, and the soul – it also concerns the general principles of nature and scientific knowledge. In the *Principia Philosophiae* Descartes is presenting not just a particular physical system but also an *example* of how a physical system should be constructed. This much at least must be left of the original Cartesian method. The physics he sketches serves at least implicitly as a specification of certain minimal conditions to be placed on a mechanistic physics. This is not to say that Descartes' physics is supposed to illustrate a (secret) philosophy or metaphysics of science that was cognitively otherwise represented than in its particular exemplification, but merely to say that we should interpret Descartes as aiming at general assertions, and that it may be enlightening to view his tokens from the more general perspective of the types they may instantiate for us.

I want to distinguish three basic principles of theory construction that the core of Descartes' physics as presented in the *Principia Philosophiae* (and the *Dioptrique*) can serve to illustrate. These principles can be characterized provisionally as *identity*, *interaction*, and *reduction*. We would today most likely take them methodologically as prescriptions for theory formation; but a seventeenth-century rationalist was more likely to take them metaphysically as a priori postulates about the world.

1.1 Identity – the conservation of matter and motion

The principle of *identity* demands that the conceptualisation of the system studied by science must specify in physical terms what exactly it means to be the *same* system over time. This tells you basically what happens to the system when *nothing* happens to it – not when nothing happens *in* it, but *to* it – what it means to be an isolated system. Descartes' instantiation of this principle is the conservation principle that those fundamental magnitudes that constitute the identity of the world system over time are invariant. These magnitudes are for Descartes 'real and positive' – anachronistically speaking, they are scalar.[2] He justifies this principle by appealing to God's constancy and immutability – or more precisely to the fact that it is 'most consonant with reason' to ascribe him such constancy. However, God's constancy does not determine the physical content of the conservation quantity; it only determines that there must be one, which the physicist must specify. In the *Principia* Descartes explains that the relevant magnitudes are the quantity of matter (measured by volume) and the quantity of motion (measured by scalar speed).

> [God] in the beginning created matter along with motion and rest, and now solely by his ordinary concourse conserves as much motion and rest in this whole as he put there at that time. Admittedly, this motion is nothing in the matter moved but a mode of it. But nevertheless it has a certain and determinate quantity; and this, we easily understand, can be ever the same in the universe as a whole though it changes in individual parts. . . . it is most consonant with reason to think that from the mere fact that God moved the parts of matter in various ways when he first created them and conserves all this matter in completely the same mode and in the same proportion as he first created it, he also conserves as much motion in it.[3]

A system of matter like the world remains the same system only if it always remains the same size and if there is always the same amount of 'motion' going on in it. A smaller or larger system is not the *same* system, and a more interesting system (with more action going on in it) or a more boring one (with less action going on) is not the same system either. The conservation of these two quantities defines the kind of system for which the laws of physics are supposed to hold. The physical theory itself must then specify in a conservation law what exactly the conserved quantities are. But the details of exactly what changes occur in the constellations of bodies are not specified by this conservation law in any way.

Descartes' concept of force or motion, as developed in various writings and applied to impact in the *Principia*, is most easily grasped if we first look at its extension. The concept of force was supposed to cover at least the following phenomena:

1 the ability of a body in motion to *act* upon other bodies,
2 the work necessary to *raise a load*, or the work performed by lowering the centre of gravity of a complex machine, and
3 the causal action (of God or whatever) that *is conserved* in the world system.

The first area of application of the concept of force is what I want to clarify in Sections 3 and 4 below after explicating the other two briefly here. The second area is fairly straightforward: traditional statics conceived of force on the model of the lever, the relevant components being weight and height or weight and length of the lever. This is what *force* primarily meant from Archimedes to Stevin.

It is in the third area that force becomes definitive of the identity of the system of matter; and incorporating this area into the conceptualization of force is Descartes' major contribution to modern physics. Force is what defines the causal closure of the material world. Descartes measured this quantity of causal action (called variously *force* or *motion*) in the ideal case by the product of size and scalar speed. An anachronism that cannot be avoided anyway can help us to clarify this notion, if we look briefly at what Descartes' successors made out of this so-called 'force'. In his *Brevis demonstratio* of 1686,[4] Leibniz showed that the correctness of the Cartesian measure of conserved force – interpreted as scalar momentum ($|mv|$) – coupled with Galileo's law of falling bodies and the law of the lever would allow the construction of a mechanical *perpetuum mobile*. There were two obvious ways out of the problem thus created. Leibniz and his supporters held fast to the assumption that the causal action conserved in the world was real and positive (scalar), and they changed its *measure* from $|mv|$ to mv^2. The more orthodox Cartesians on the other hand – and later the Newtonians as well – held on to the *dimension* mv but interpreted the Cartesian quantity of motion as a directed quantity, that is, as vector momentum. Both quantities (mv and mv^2) were known, since Huygens' work on impact of 1668, to be conserved in elastic collisions.[5] Neither of these two quantities is precisely what Descartes meant by force or motion; they are merely what his successors *had* to mean in order to be consistent. Thus, when we today try to make sense of what Descartes himself meant, we are forced to interpret his *force* as 'something like' our momentum or 'something like' our kinetic energy – only different. 'Scalar momentum' is what many historians want to call Descartes' conception of force; but we might just as well call it 'dimensionally reduced kinetic energy'. I think it makes best sense to conceive of Cartesian force as 'something like' our energy (measured wrongly), since at least in classical physics it is the conservation of mass and energy that define the identity of the system of matter.[6]

1.2 Interaction – the laws of nature

The second principle, *interaction,* specifies that in a mechanistic system – that is, a system conceived as determined by the properties and interactions of its parts – there must be a physical rule governing the behaviour of the system-elements in simple interactions and in the absence of interactions. Descartes' instantiation of this principle is specified physically in three Laws of Nature (*Princ.* II, arts. 37–52), which define what the fundamental interactions of bodies within the system are and how bodies behave in these interactions as well as in their absence. These Laws tell us what *individual* bodies do when something happens to them and when nothing happens to them.

Descartes' First Law of Nature (often compared with our law of inertia) determines what a single individual body does of its own accord, that is, what happens to it *in the absence of interactions*.[7]

> Each and every thing insofar as it is simple and undivided always remains in the same state as far as it can, nor does it ever change except by external causes. Thus, if a particular part of matter is square, we can be sure without more ado that it will remain square forever, unless something coming from outside changes its shape. If it is at rest, we hold that it will never begin to move unless it is pushed into motion by some cause. And if it moves, there is equally no reason for thinking that it will ever cease this motion of its own accord and without being checked by something else. Hence we must conclude that whatever moves, so far as it can, always moves.[8]

If nothing happens to a body, it retains its size, its shape and its state of (scalar) motion or rest; that is, in the absence of interactions a simple body conserves its basic *properties* or *modes*. The physically most important aspect of this is of course the conservation of 'motion' in an isolated, non-interacting body. The law specifies not just that staying the same in isolation needs no explanation, it also explains what staying the same means in physical terms. For a single body, staying the same also means – analogously to the world system – conservation of size and scalar speed.

Descartes derived this First Law (allowing for the usual gestures towards God's constancy) from the logic and categories of natural language. Just as the predicates of a subject do not transform themselves into their contraries without a reason, so too the properties of bodies do not become their opposites without a cause, and specifically, motion (a basic property of bodies) does not become its opposite, rest, without a cause. Thus a body retains its state of motion in the absence of external causes or interactions. 'For rest is contrary to motion, and nothing can be carried by its own nature towards its own contrary or towards its own destruction.'[9]

The Second Law of Nature specifies the conservation of the *determination* of an isolated, non-interacting body's motion.[10]

> Each and every part of matter considered separately never tends to continue moving in any oblique lines but only in straight lines . . . It is manifest that everything that moves is determined in the individual instants which can be specified as it moves, to continue its motion in a given direction along a straight line, and never along a curved line.[11]

Just as the first-order properties or modes of a body do not change without a cause according to the First Law of Nature, so, too, the second-order properties, the modes of the modes or the determinations of the properties do not change without a cause according to the Second Law. Descartes only mentions one such second-order mode: the determination of motion. At first glance it might seem as if only the directional aspect of determination is said to be conserved according to this law. The direction of motion was not covered by the First Law, and thus its conservation must be specified explicitly; but the conservation of the *quantity* of determination might seem to be just a simple consequence of the conservation of motion in an isolated body. However, Descartes probably intended more – and he definitely needs more. Without an explicit statement that the *quantity* of (non-interacting) determination is conserved, it would not be clear in the case of interaction that the quantity of that *part* of a determination that is not involved in the interaction is in fact conserved, even if the aggregate determination and the quantity of motion change. This aspect of the Second Law was applied in the *Dioptrique* (see below) to explain reflection and refraction. In the absence of interactions a body retains not only its motion but also the determination of this motion in a straight line; and in an interaction a body retains unchanged that *part* of its motion's determination that is not involved in the interaction.

The Third Law of Nature[12] specifies what happens to two otherwise isolated bodies when they interact with each other – and *only* with each other. The ideal case deals with two bodies that are 'neither impeded nor assisted' by surrounding bodies. Since Descartes' own version of a mechanistic physics envisioned one and only one basic kind of interaction – impact – he provides only one law governing one kind of interaction. The Third Law specifies what happens to the – otherwise conserved – modes of bodies (motion and rest) and to the modes of their modes (their determinations) when two bodies interact, that is, 'encounter' each other. The technical term is *occurrere* (*occursus*) in Latin and *rencontrer* (*rencontre*) in French – generally translated as 'collide' ('collision'). Collision is the *only* fundamental interaction of which matter is capable, so that the term 'encounter' always refers to a collision. This law, Descartes says, 'covers all the particular causes of the changes which bodies undergo'.[13] All other apparent material interactions, in particular all phenomena of cohesion, are purely derivative in nature. They are contingent further consequences of this one fundamental form of interaction. But the Third Law of Nature, at least as further elaborated in the seven impact rules, governs only two-body interactions in the same line, that is, in one dimension.

1.3 Reduction

A third principle, *reduction,* is needed to guarantee that all the various phenomena of the system studied can be derived through a series or combination of simple interactions. We need rules for reducing complex interactions step by step to the simple, basic ones. Descartes says little about this in the *Principia*, though he does assert that many-body collisions consist ultimately of two-body collisions, and does intimate that three-dimensional (spatial) interactions can be dissected into a series of one-dimensional (linear) interactions.[14] However, the tradition of natural philosophy provided the conceptual means for this reduction, in the logical doctrine of contrary oppositions and in the parallelogram rule for compounding and resolving motions. Descartes does deal with these questions in the *Dioptrique* and in letters, where he applies the doctrine of oppositions and the parallelogram rule to *determinations*. The oblique reflection of a tennis ball hitting the court surface, for instance, is 'reduced' to a one-dimensional vertical interaction with (opposition to) the surface and a one-dimensional horizontal lack of interaction with the surface.

2 Determination as a mode of motion

The concept of determination is perhaps the most difficult concept of Cartesian physics, and a case can be made that none of Descartes' own seventeenth-century followers – with the possible exception of Spinoza – really grasped what he meant by the term. Determination is 'something like' our *momentum* except that it is not an independent quantity. I shall try to clarify the notion of determination by looking first at the geometry of its mathematical representation and then at the logical grammar of its linguistic representation.

2.1 Geometry

The concept of determination was first presented in 1637 in the *Dioptrique*,[15] where it is introduced as a directional physical quantity, which like any other quantity can be arbitrarily divided or resolved into whatever parts we imagine it to be composed of:

> It should be noted that the determination to move in a certain direction just as motion itself, and in general any sort of quantity, can be divided into all the parts of which we can imagine that it is composed.[16]

The particular manner in which this quantity is to be 'divided' into its parts and recompounded out of them is specified by the parallelogram rule that was traditionally used for resolving and compounding *motions*.[17] According to this rule (see Figure 4.1), a *point* A that moves to B on line AB in the same time as *line* AB itself moves to CD will traverse the line AD. Thus the motion compounded of AB and CD is equal to AD. Descartes' on the other hand, does not apply the parallelogram rule to motions; and

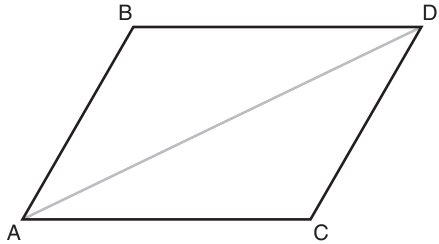

Figure 4.1 The parallelogram of *motions*. If point A moves to C on line AC at the same time as line AC moves to BD, it will describe the line AD.

he carefully distinguishes between motions, which are independent of a particular direction, and determinations, which are directed. Motions, as 'scalar' quantities, are not resolved and compounded by this traditional rule – only their determinations are so resolved and compounded.[18] Thus, the first constituent of the meaning of the term 'determination' is that it is that physical quantity resolved and compounded according to the geometrical parallelogram rule.

The notion of determination can be illustrated on the simple example of reflection used by Descartes in the *Dioptrique*.[19] Figure 4.2 shows the motion of a tennis ball – or a light ray – bouncing off the court surface. Descartes assumes that its motion is *uniform* and that scalar motion is conserved in spite of the collision with the surface of the court. Given that the ball travels from A to B during the first unit of time, where will it be, Descartes asks, after the second unit of time? Since the radius of the circle represents the distance covered in one unit of time and the ball is at B, the centre of the circle, at the end of this first unit, we can infer that the ball will be back somewhere on the circumference of the circle at the end of the second unit of time. The particular radius drawn from A to B

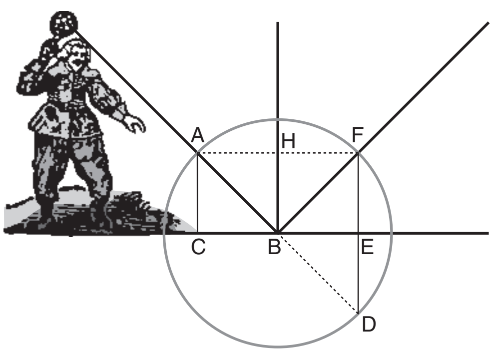

Figure 4.2 The determination AB of ball A's motion can be resolved into two orthogonal components AC and AH. Component determination AC is directly opposed to surface CBE, and component AH is not at all opposed to it. From *Dioptrique*, AT vi. 95.

represents the *determination* of the ball's motion during the first unit of time. The *length* of this line represents the motion; the absolute value of the determination is equal to the motion. This does not yet tell us what happens to the determination of the ball's motion when it hits the surface; but the behaviour of one *part* of its determination can indeed be specified.

The determination AB can theoretically be divided into two parts in an infinite number of ways, but Descartes points out that the perpendicular to the surface is the line in which the determination is *opposed* to the surface: only that *part* of the determination that is normal to the surface (i.e. AC) is actually involved in the interaction at B, and only this part can be compelled by the interaction to change in any way. This may seem somewhat arbitrary, but no one in the seventeenth century would have thought to dispute that the perpendicular is the line of direct or full opposition.[20] The remaining part of the determination (AH) is parallel to the surface and is not involved in the interaction, and so there is no reason why it should change. The surface of the court specifies a coordinate system and provides one of the sides of the parallelogram to be constructed (CB); and the clear-cut distinction between opposition and non-opposition demands that the angle ACB be a right angle. Thus, the parallelogram constructed *must* be a *rectangle*, and the division of the determination AB into two orthogonal parts AC and AH is completely determinate. Although a determination may in principle be divided into many different pairs of components, it is the two orthogonal components specified by the surface of collision that are physically relevant. A different surface would specify a different resolving rectangle, but each given surface specifies only one decomposition of determinations. As Descartes points out to Fermat:

> The determination to move can be divided (I mean really divided and not at all in the imagination) into all the parts of which one can imagine it to be composed; there is no reason at all to conclude that the division of this determination, which is done by the surface CBE, which is a real surface, namely that of the smooth body CBE, is merely imaginary.[21]

Now, since the component-determination AH is not involved in the interaction with the surface in any way, it remains unchanged in the second unit of time and thus will be one component of the new compound determination of the ball's motion in this second time unit. To find the missing component-determination, we note that scalar motion is conserved and that the new compound determination of the ball's motion must be equal in absolute value to this motion. We can easily see that the ball must arrive at the circle at point F, where line FD cuts the circumference above the surface. From this we can also *infer* that the (interacting) component-determination AC has been replaced by EF. But it is important to note that this *reversal* of the downward determination is not used to explain reflection; it is itself a simple consequence of the explanation of reflection.

One peculiarity should be noted. It is only the lengths of the radii AB and BF that are said to represent motions. These two lines represent the determinations of the motion of tennis ball A in the two units of time, their lengths represent *A*'s motion. The other lines AC, AH, HF, EF, etc. represent component-determinations; *but the lengths of these lines do not and may not represent motions.* If the lengths of the sides of the parallelogram were to represent scalar motions, there would be more motion in the world when determinations are resolved than when they are compounded, and different amounts depending on how they are resolved. The parallelogram rule could only be applied to *motions* if these were directed quantities. Thus, it can be seen that the geometrical representation taken by itself is in some regards indeterminate. Some lines represent determinations *and* motions; some lines represent only determinations; and you have to be *told* which are which. Which lengths in a given geometrical figure represent motions is specified only by the *linguistic* representation of the phenomenon in the text that accompanies the figure.

Summing up the what the geometry of this example from the *Dioptrique* tells us: the directional aspect of determination can be changed without changing the quantity of motion but the *quantity* of the determination – at least that of the compound determination – is tied to that of motion. Thus, determination is only a semi-independent quantity. Furthermore, while a determination is equal (in absolute value) to its motion, its (possible) component parts are apparently without any determinate quantitative relation to the (possible) component parts of the motion.

2.2 Logic

How is determination related to motion? This is specified by the linguistic representation of the concepts. The second constituent of the meaning of 'determination' is the logical or grammatical relation of a determination to its motion. A motion and its determination are related as subject and predicate or, perhaps better, as adjective and modifying adverb. A determination is quantitatively and dimensionally equivalent to the force or motion it determines because it is itself just a mode of that force.

If motion is a mode of a body, then determination is a mode or modification of this mode, a sort of second-order property of bodies (see Figure 4.3). In its quantitative aspects Descartes generally compares it with the *surface* of a body. Just as a body has two primary modes, shape and state of motion, so too does each of these primary modes have a further specification: *shape* has a surface and *motion* has a determination. In response to Hobbes Descartes argued that just as a surface has a quantity (its area) which can be divided into parts – for instance, the surface of a cube can

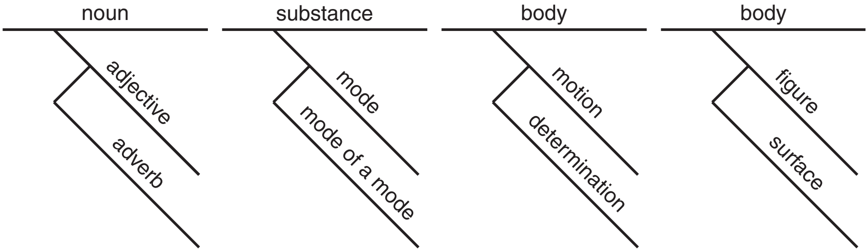

Figure 4.3 The logical grammar of the concept of determination. Motion is a mode of bodies and determination is a mode of motion, just as figure is a mode of bodies and surface is a mode of figure.

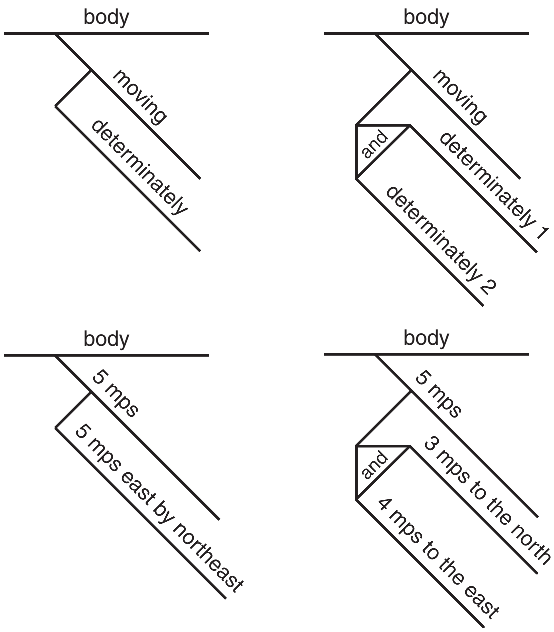

Figure 4.4 The determination of a motion can be divided into parts; but the parts of the determination are neither parts of the motion nor modes of parts of the motion: they are component modes of the motion.

be divided into six square faces – so, too, does motion have a determination that can also be divided into its parts (Figure 4.4).[22] The important point is that the determination is a genuine quantity, it consists of parts; it is not just the *direction* of motion. But it is not itself a *motion*, nor is it a part of a *motion*; and a part of a determination is also neither a part of a motion nor even the determination of a part of a motion. Similarly, the surface of a body is not the shape or part of the shape of the body, and the parts of the surface are not parts of the shape nor are they surfaces of parts of the shape or the body. The six square faces of a cubically shaped body are

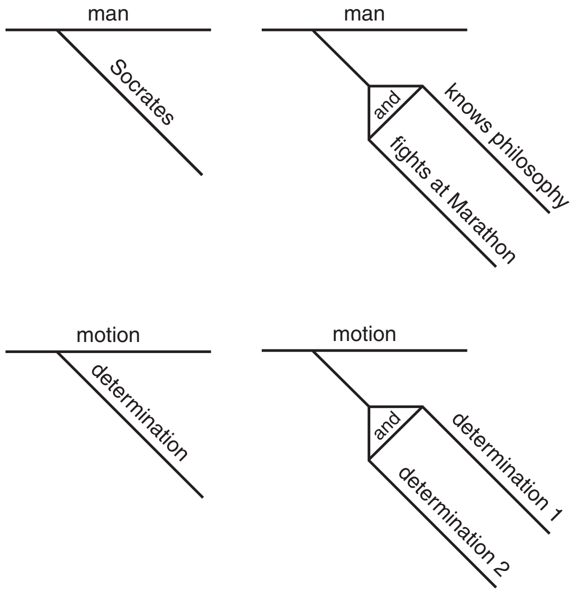

Figure 4.5 Descartes' analogy between modes of a mode and predicates of a subject: determination relates to motion as a predicate to a subject or, more precisely (taking 'man' itself as a determination of a substance), as an adverb to an adjective modifying a noun.

parts of the *surface* of the cube; they are not (complete) surfaces of parts of the cube. One more logical example (Figure 4.5) should help to clarify how the determination of a motion can be said to have parts: for instance, the property or determination of being Socrates can have parts. Let us say that having a knowledge of philosophy and fighting at Marathon are the two component-determinations of the property of being Socrates. It does not follow that either of these component-determinations can be predicated of any one of the man Socrates' component-parts.[23] The parts of a mode of a subject are not modes of parts of the subject. Thus the parts of the mode of a body's motion are not themselves modes of parts of that motion. Although motion itself is just a *mode* of a body or a property of a substance, in relation to determination it may be viewed as the subject of a property. Just as parts of a compound adjective modifying a noun are not themselves nouns or parts of nouns, so too the parts of a compound adverb modifying an adjective (that modifies a noun) are not themselves adjectives.

Cartesian determination is a hybrid of directionality and the absolute value of a motion. It is a directed quantity with the same absolute value as the motion which it modifies; it is thus only semi-independent. Its direction can vary independently of the motion it modifies, but its quantity cannot vary: it is always given by the quantity of motion. However, since any determination can be subdivided in various ways according to the parallelogram rule, it is possible for the quantities of the component-determinations to vary a great deal, so long as their vector sum does not.

2.3 Is determination just projection on a line?

Descartes' readers have always been perplexed by the concept of determination; and there has always been a tendency to view determinations either as actual motions or simply as directions. These two alternatives were already presented as exhaustive by Pierre Fermat in 1637; and most commentators until Sabra went for one of the two options.[24] Both are eminently reasonable interpretations of the geometrical representation, if this is taken alone without the constraints placed on it by the linguistic representation. But both options are unacceptable.

The geometrical representation alone may be taken either as depicting the projection of a motion on a line of direction, or as applying the traditional parallelogram rule. If determinations are taken as directions or as the *projections* of motions on lines of direction, they could not be part of the causal explanation of anything.[25] The projection or the shadow of a tennis ball in the first unit of time does not constrain in any way the behaviour of the ball in the second unit of time. A motion may be projected on two different lines of direction, but the projections need not form the sides of a parallelogram with the projected motion as its diagonal. If, on the other hand, determinations are governed by the parallelogram of motions, it would be reasonable to take them as actual motions and parts of motions.[26] In this case there would be an immediate conflict with the conservation of scalar motion. Thus each of these alternative views of determination is systematically incompatible with Descartes' project of a mechanistic physics, and each is plausible as an interpretation only if we abstract from the logical representation of the concept. I shall deal with the second alternative only very peremptorily since it implies an obvious contradiction to the fundamental conservation law, but I shall take up the first alternative in some detail.

Even the best commentators often attribute to Descartes the view that the component parts of a determination are parts of the motion itself – or perhaps determinations of parts of the motion. The main reason for this is that Descartes actually says so explicitly. In a letter to Mersenne concerning some criticisms of the Jesuit scientist, Pierre Bourdin, Descartes remarks:

> But I believe that what perplexes him is the word *determination*, which he wants to consider without any motion, which is chimerical and impossible; in speaking of the determination to the right, I mean all that part of the motion that is determined towards the right.[27]

Alan Gabbey, who has done some of the most important work on Descartes' concept of determination, observes that this is 'the nearest Descartes came to a clear definition of the notion',[28] and many commentators follow him here. However, as I have indicated above and argued at length elsewhere,[29] far from being Descartes' clearest presentation of the concept, this is most likely a slip on Descartes' part, since the characterization immediately leads to contradiction with the conservation of scalar motion. If the entity resolved and compounded by the parallelogram rule is a motion, then the quantity of scalar motion is going up and down all the time. This remark of Descartes rather provides evidence of the extremely problematical character of the concept determination since even its inventor, Descartes, gets it wrong sometimes.

Fermat's first alternative, that determination is merely direction, has no such explicit support; but there are at least two well known passages from letters by Descartes written in response to criticism of his *Dioptrique*, that have misled many commentators to look upon determination as mere direction or projection on a line of direction and to treat motions and determinations as genuinely independent magnitudes, so that either one can be varied independently of variation in the other.[30] In particular, a (quantitative) change of speed is thought to be able to occur without any change in (quantity of) determination. In a letter to his former collaborator Claude Mydorge rebuffing Fermat's criticisms of the *Dioptrique*, Descartes wrote:

> [Fermat] would have it that I supposed such a difference between the determination to move here or there and the speed, that they are not found together and cannot be diminished by the same cause, namely by the cloth CBE: which is contrary to my meaning and contrary to the truth; although this determination cannot be without some speed, *nonetheless, the same speed can have various determinations and one and the same determination can be joined to various speeds.*[31]

And in a letter to the previously mentioned Jesuit scientist Bourdin (via Mersenne) responding to criticism, Descartes wrote similarly:

> It should be noted that the collision with the surface CBE divides the determination into two parts but does not divide the force, nor is this surprising, since though a force cannot be without a determination, nonetheless, *the same determination can be joined to a greater or lesser force and the same force can remain though the determination changes in whatever manner.*[32]

In each of these passages Descartes seems to be asserting that the determination and the speed of a body are independent quantities and can vary independently of one another. However, each passage can also be taken as literally true on the interpretation I have presented above. Each passage contains two assertions: (1) *different* determinations can be modes of the same speed, and (2) the *same* determination can be attached to different speeds. Only the second assertion gives cause for concern. The first proposition simply states that two *directionally* different determinations can go with the same scalar speed or force. This is unproblematic: two determinations are *different* if they differ in one of their two aspects, quantity or direction. However, since two determinations can only be the *same* if they are the same in *both* aspects, size and direction, it would seem that the second proposition of each quote contradicts everything that I have been saying about determination – and, again, these are Descartes own words. If two motions with different speeds can have the same determination, then we must take the concept to mean simply direction. If determination is not simply direction but also has a quantity, how could the *same* determination be joined to two different speeds? In Descartes' official presentations, at least as I have reported them, any change in the quantity of motion of a body (the length of the radius of the circle) necessitates a change in the quantity of determination, too; only the directional aspect of determination can change without any change in speed or remain the same for different speeds. Descartes seems here not only to be directly contradicting his own considered opinion but also to be violating the geometry of his representations.

In each of the two cases cited Descartes is extrapolating from a particular example (refraction), in which a change in speed occurs, horizontal determination is conserved, and an accompanying change in aggregate determination is considered. That is, the concrete question being asked is whether the 'same' (horizontal) determination of a tennis ball's motion can be 'joined' to its changed speed after refraction. In refraction at point B (see Figure 4.6), the incident ray or the tennis ball trajectory is said to

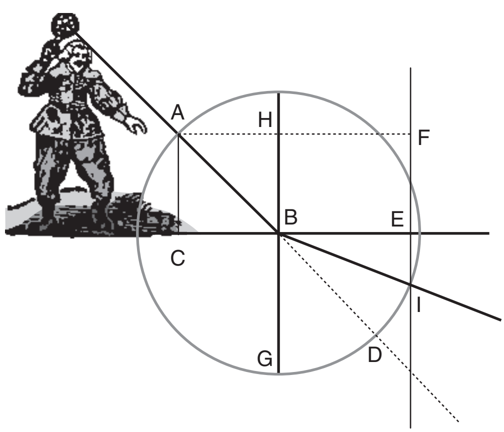

Figure 4.6 The component determination AH of ball's motion A to B is not involved in the interaction at B and, represented by HF, can be 'joined' to the quantitatively smaller motion from B to I. From *Dioptrique*, AT vi. 97.

have a determination (AB), which is divided into components (AH) and (AC). These *components* are of course also called 'determinations'. After refraction (as opposed to reflection) the tennis ball has (say) a *decreased* speed and a determination changed in both quantity and direction. For technical reasons, Descartes always represents the changed speed of the ball in the second unit of time not by a different radius length below the surface CBE, but rather by a radius of the *same* length – with the appropriate changes in the scale of measure, the same length now representing a smaller or larger quantity of motion and determination (in this particular case, a smaller quantity).[33] Note that, if we take the radius as unity, then AH, the horizontal component-determination, represents the sine of the angle of incidence and BE, the conserved horizontal determination, represents the sine of the angle of refraction. The relation between the two representations of the same component-determination *is* the sine law of refraction. Descartes asserted in the *Dioptrique* that the (*component*) determination AH, which was joined to the speed of the body from A to B, is unaffected by the interaction with the surface CBE in B, since it is parallel to CBE. Thus it will be conserved unchanged in the second unit of time and can be represented by the line BE or HF (which is longer due to the change of scale). This same component-determination can then be joined to the altered speed of the body from B to I as one component of its new determination. Remember, however, that the radius of the circle below the surface (the length of which represents the *changed* motion) also represents the determination of the tennis ball's motion after refraction. The quantities of motion and of determination are still equal in the representation: if the motion is smaller so is the determination. Thus, when Descartes says that the 'same' determination is 'joined' to two different speeds he can only be asserting that one of the *component* determinations into which AB was resolved (that is, AH) can be used to help compound the determination of a different motion (from B to I) and thus can be 'joined' to a different motion. He is not asserting that the same compound determination is attached to two different speeds – this would belie his own representation – but only that the same component–determination that was originally part of the determination of one motion (but not involved in any interaction) is also part of the determination of a quantitatively different motion. It is precisely *because* the same (component) determination can be joined to two different speeds that the sine of the angle of refraction has a constant relation to the sine of the angle of incidence in the first place.

Summing up, when Descartes says that 'the same determination can be joined to various speeds', he does not mean that speeds of 4 mph and 5 mph can have the same determination in his technical sense; but he also does not merely mean that different sized motions may point in the same direction. He means that a component–determination that is not involved in a particular interaction (and thus is conserved according to the Second Law of Nature) will be part of the mode of whatever new motion ensues after the interaction. Put more generally: the compound determinations of two different speeds can each be resolved into two components respectively in such a way that one component of each is the same in both quantity and direction, just as two different wholes can have a part in common.

3 Force and the rules of impact

The second problem to be clarified is the precise relation of the force involved in impact to the better understood forces cited by the conservation law and the law of the lever. Force, as the ability of one body in motion to act upon another is decisive for the lawlike description of interactions governed by the third Law of Nature:

> The third law is this: when a body that moves encounters another, if it has less force to continue in a straight line than the other has to resist it, it is deflected in another direction, and retaining its quantity of motion, it gives up only the determination of the motion. If, however, it has more force, it moves the other body with it and loses as much of its motion as it gives to the other.[34]

When two bodies with incompatible modes encounter one another, the outcome of the encounter is determined by their relative forces: some change in their modes will occur so that the incompatibility is removed. The description of a given body in a two-body interaction or 'encounter' has, according to this formulation of the law, two relevant dimensions: determination and motion; and two different relations are under consideration: the body is weaker than the one it hits or it is stronger. However, in the actual elaboration of this law in the impact rules, not only is a third kind of opposition introduced, but also a third relation between the strengths of the two bodies. Note also that according to this law a body can give up (*amittere*) its determination without qualification, but it can only lose (*perdere*) as much of its motion as the other body acquires.

Officially, there are only two basic contrarieties in an interaction: 1 between the modes of bodies, motion and rest, and 2 between the modes of modes, determination in one direction and determination in another direction:

> Strictly speaking, only a two-fold contrariety is found here. One is between motion and rest, or also between swiftness and slowness of motion (that is, to the extent that this slowness partakes of the nature of rest); the other is between the determination of a body to move in a certain direction and the encounter in this direction with a body which is at rest or moving in a different manner; and this contrariety is greater or lesser in accordance with the direction in which the body that encounters the other is moving.[35]

However, as this passage indicates, each of the basic pairs of contraries may either involve polar opposites or admit of degrees, so that there are actually four relevant possibilities. Between the polar contraries motion and rest there might also be intermediates such as slower and faster motions: a greater or lesser opposition between swiftness and slowness. And besides the direct opposition of two determinations in one line there may be many degrees of oblique opposition between two determinations in a plane or a space. Only the first of these two kinds intermediate oppositions is dealt with explicitly in the *Principia,* which sticks to oppositions in one dimension. The oblique opposition of determinations, on the other hand, would require us to consider two or even three dimensions, and this is beyond the scope of the deductive core of the *Principia*.[36]

The three relevant possibilities of incompatible modes in the (one-dimensional) encounter of two bodies are thus (A) opposed determinations, (B) opposed states of motion, and (C) graded opposition between faster and slower motions. For each of these kinds of opposition, the encountering body B under consideration can be stronger or weaker than the body C that it encounters. Furthermore, it is obvious that the two bodies might not differ at all in force and could thus be equally strong. Although the exact formulation of the Third Law does not actually countenance such a case, Descartes must implicitly be envisioning certain symmetry conditions, since three of his impact rules do in fact deal with *equally* strong bodies. A system with three kinds of modal conflict and three kinds of power relations between the conflicting parties generates nine cases to be considered – and, taking into account that the seventh impact rule actually consists of three variants, Descartes has nine rules of impact.[37]

Descartes conceives of collision on a conflict model. Bodies interact only if one or more of their modes are incompatible: two bodies meet, a modal conflict arises between them that has to be resolved, and the stronger body wins. Since strength depends on size and leverage, the traditional way of deciding which of two bodies is 'stronger' was to put them on a scale, and most seventeenth-century discussions of impact take their cue from statics and the law of the lever.[38] The background in statics has at least two important consequences for the conceptualisation of interaction. First of all, in statics in a symmetrical situation nothing happens, but a small change from equilibrium can lead to a disproportionate disequilibrium: there is a discontinuity of effects. Second, in the practical application of statics in the use of the simple machines there is an intuitively plausible difference between the *force* applied and the *load* moved; and this distinction is reflected in Descartes' distinction between the strength of the 'encountering' body and the strength of the body encountered (the load). The application of statics to collision is fairly straightforward when both bodies are in motion and only the determinations are opposed, as in Descartes' first three impact rules. In these cases he treats the size and speed (distance per unit time) of a body just like weight and the length of the balance arm. Difficulties with the statics model arise for Descartes when he moves to the opposition between motion and rest. If one body is at rest, how do we represent the quantity of its rest? Descartes stipulates strict symmetry between the two contrary modes, motion and rest: If the velocity of one body is represented by the length of a lever then the quantity of rest of the other body is represented by a lever of the same length. For equal bodies one has as much rest as the other has motion. In an opposition between rest and motion the bigger body is always the stronger.

Besides the implicit symmetry considerations derived from the phenomenon of equilibrium, Descartes also invokes an implicit extremal principle that is made explicit only in a letter to Clerselier about a year after publication of the *Principia*. This principle stipulates that the change that occurs so as to reconcile the incompatible modes of bodies is the least amount that suffices to remove the conflict:

> When two bodies which have in them incompatible modes encounter one another, some change in these modes must unquestionably occur in order to make them compatible, but this change is always the least possible; that is, if they can become compatible through the change of a certain quantity of these modes, a greater quantity will not undergo change. And we must consider that two different modes are in the motion [*mouvement*]: one is the motion [*motion*] alone, or the speed, and the other is the determination of this motion [*motion*] in a certain direction; of these two modes, one changes with as much difficulty as the other.[39]

This principle of minimal modal change[40] alleviates some of the underdetermination of the outcome of collision, by singling out one of the possible outcomes consistent with the Third Law as formulated in the *Principia* (minimal modal change) as the actual outcome.

The order of the impact rules as Descartes presents them is determined by the increasing complexity of the opposition between modes: (A) simple opposition of determinations, where both bodies are in motion and only their determinations are opposed; (B) double opposition between states of motion and determinations, where one body moves, the other rests, and their determinations are opposed; and (C) double opposition between *intermediate* states of motion and determinations, where both bodies move in the same direction but one overtakes the other. Within each of the three levels, however, there is no strict order (see Figure 4.7). Sometimes Descartes begins with the equilibrium case (Rule 1), sometimes with one of the cases of disequilibrium (Rule 4, 7a).

The first three impact rules illustrate the statics model very clearly. For the simplest form of opposition we get simple solutions:

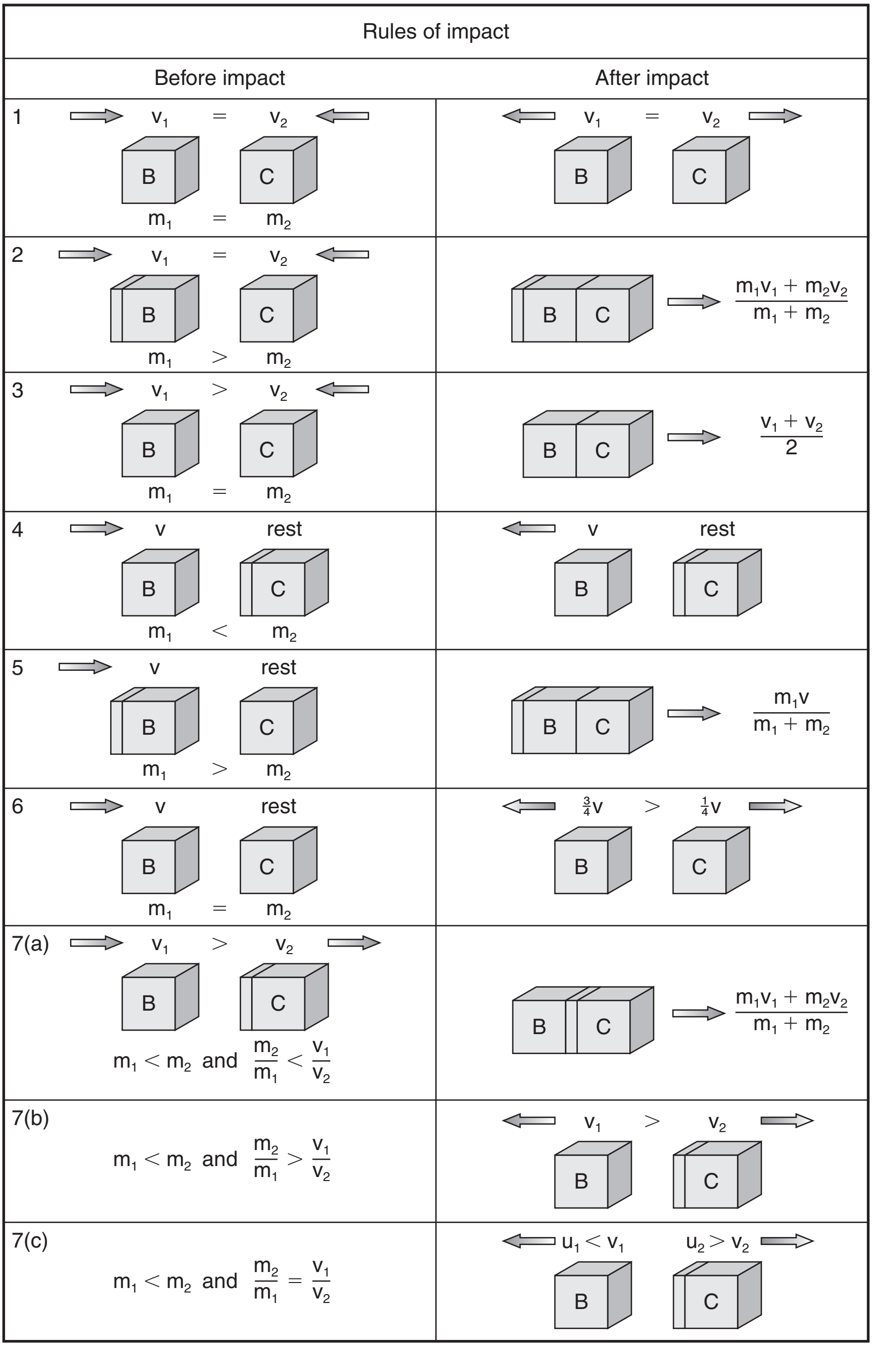

Figure 4.7 Descartes' impact rules. In the *Principia Philosophiae*, the moving body always comes from the right, not from the left, as opposed to contemporary representations.

Rule 1: if the arms of a balance are of equal length and the weights are equal, the scale is in equilibrium, and the conflict is a draw.

Rule 2: if the weights are equal, the longer arm (greater speed) determines the winner.

Rule 3: if the lengths of the arms are equal, the heavier (larger) body wins.

According to Descartes' official definition of force or motion as size × speed, the cases dealt with in Rules 2 and 3 should be the same: body B (the force) is stronger than body C (the load). The case in which the encountering body B has less force than the encountered body C is not dealt with at all here, although it is dealt with in each of the later triplets of opposition. Apparently, there is no reason in this case of collision why one body rather than the other is to be viewed as the force or the load, so Descartes distinguishes instead between two different dimensions in which body B may be stronger: size and leverage. In the equilibrium situation (Rule 1), each body retains it motion (and its physical integrity) and reverses its determination. In both of the disequilibrium situations the weaker body loses its determination, gains a new one, and is practically absorbed into a new and larger body travelling in the stronger body's original direction, so that the quantity of motion of the new compound body is equal to that of the two bodies before.[41]

The consequences of the statics model become particularly clear in the notorious *Rule 4*, which states that when a smaller moving body encounters a larger resting body, it rebounds with the same speed in the opposite direction. As a consequence, no matter how fast body B is, it will never budge the resting body C as long as it is just a little bit smaller than C. If, on the other hand, the moving body B should be just a little bit larger (*Rule 5*), it would push body C in front of it transferring to it the appropriate part of its own motion and determination. And if the two bodies were exactly equal in size (*Rule 6*) there would be a kind of compromise between the cases of Rule 4 and Rule 5, where some motion is transferred and some determination lost and gained by each body. Note that the difference between equilibrium and disequilibrium may be almost infinitesimal, but the difference in outcome between winning and losing a conflict can be very great. There is no proportionality between the size of the force *difference* and the size of the victory: a very small difference in strength can tip the scales. The discontinuities of Descartes' impact rules, which have been seen as a major weakness ever since Leibniz, are the inevitable consequences of the statics model. The intuition behind this conceptualization of force can be seen in a remark made by Descartes three years before the *Principia* in a letter to Mersenne for Hobbes. In the course of an argument about reflection, Hobbes had asserted that nothing that cannot be moved *to some extent* by a very small force can be moved by any force at all, to which Descartes replied:

> Furthermore, his assumption that *what does not yield to the smallest force cannot be moved by any force at all*, has no appearance of truth. Who would believe, for example, that a weight of a hundred pounds in a balance would yield a little to a weight of one pound placed in the other pan of the scale, just because it does yield to a weight of 200 pounds.[42]

On this model, the argumentation of Rule 4 becomes more plausible. The impact rules contain discontinuities because the model of force used is that of a deviation from equilibrium. As long as the force applied is smaller than the weight of the load, there will be no change in position, but as soon as it is the least bit larger there will be a great change.

In the third trio of impact rules, collected together as *Rule 7*, a smaller and faster (encountering) body overtakes a slower but larger (encountered) body. In this case both size of the body and length of the lever are varied simultaneously. In *Rule 7a*, where the excess *speed* of B is greater than the excess *size* of C, the outcome is analogous to Rule 5. The stronger overtaking body pushes the other in front of it, transferring to it the appropriate part of its own motion and determination. In *Rule 7b*, where the excess speed of B is less than the excess size of C, the outcome is analogous to Rule 4. The weaker overtaking body is rebuffed and reverses its determination. In *Rule 7c*, where the two bodies are in equilibrium, they divide up the necessary change in modes in analogy to Rule 6.[43]

4 Surfaces of collision

Impact or collision, as I have said, is not only fundamental to Cartesian physics, but it is the *only* interaction of which matter is capable. This is a point that must always be borne in mind. Any apparent interactions of a different kind are in the final analysis to be reduced to impact. It is well known that gravity, for instance, according to Cartesian physics is the by-product of a vortex motion which is entirely explained by impact. Also, the cohesion and resilience of a sphere in elastic impact would have to be explained in terms of the basic interaction of matter. Nonetheless, standard presentations of Descartes' impact rules seem to assume that some (even more fundamental) forces of cohesion must be involved. At least, they present impact on the paradigm of billiard balls. Descartes and his contemporaries were quite aware that billiard balls as a rule do not behave according to the Cartesian impact rules. But for Descartes ivory balls were by no means analogous to elementary particles.[44] Their resilience in collision depends on their chemical structure, which is contingent and entirely derivative.

While Descartes' first impact rule does actually seem to describe correctly the behaviour of two billiard balls, the subsequent rules are all rather less plausible on the billiard table. But this kind of representation is unwittingly misleading, presupposing as it does some kind of cohesion among the parts of the spheres. Descartes himself says that 'we cannot indeed think up any glue that would join together the particles of hard bodies more firmly than their rest'.[45] No other mode is more contrary to the motion of separation than is rest. In fact, the only reason two contiguous parts of extended matter are parts of the 'same' body is that they are mutually at rest. A part of a body resists separation from the other parts, which would demand a change in motion and/or determination, according to the First and Second Laws of Nature. The larger the part, the larger its resistance to separation. But it does not resist any more due to being 'glued' to other matter. What holds body parts together is merely parallel inertial motion. Figure 4.8 illustrates this problem. It presents a sagittal section of two equal colliding spheres, each made up of perfectly hard normal matter, that is, matter of the third element. To aid visualization, I have divided the spheres into a number of concentric discs of increasing and decreasing diameter. All the discs of each ball are in mutual rest before impact and thus make up one body. Note that at the instant of impact ($t = 0$), only the two largest discs in the middle are actually involved in the interaction. There is no reason for any of the other discs to be affected since they do not interact in any way with the discs moving parallel to them, or with anything else that they do not individually bump into. Although, according to Descartes, they do together constitute a unified body, this is due merely to the fact that they are contiguous and relatively at rest. Since the two central discs are equal in size, they retain their speeds and reverse their directions in impact according to Rule 1. The flanking discs also reverse their directions, but not until they have a reason to, namely, when they actually bump into something. Thus, the colliding spheres buckle in and change their shapes while reversing their directions.

To drive the point home, the next figure (Figure 4.9) shows what would happen to the spheres if the collision were only slightly off-centre, so that each of the discs collides not with an equally large disc, but with a slightly larger or slightly smaller disc moving with equal speed. In this case the second impact rule would hold for each pair of discs: the larger body wins and carries the smaller with it, forcing it to change its determination. The end result is that the spheres are cut almost in half and become elongated: each ends up looking like half an egg.

But these are my pictures. How does Descartes himself represent the paradigm of collision? The deformation or decapitation of bodies is not

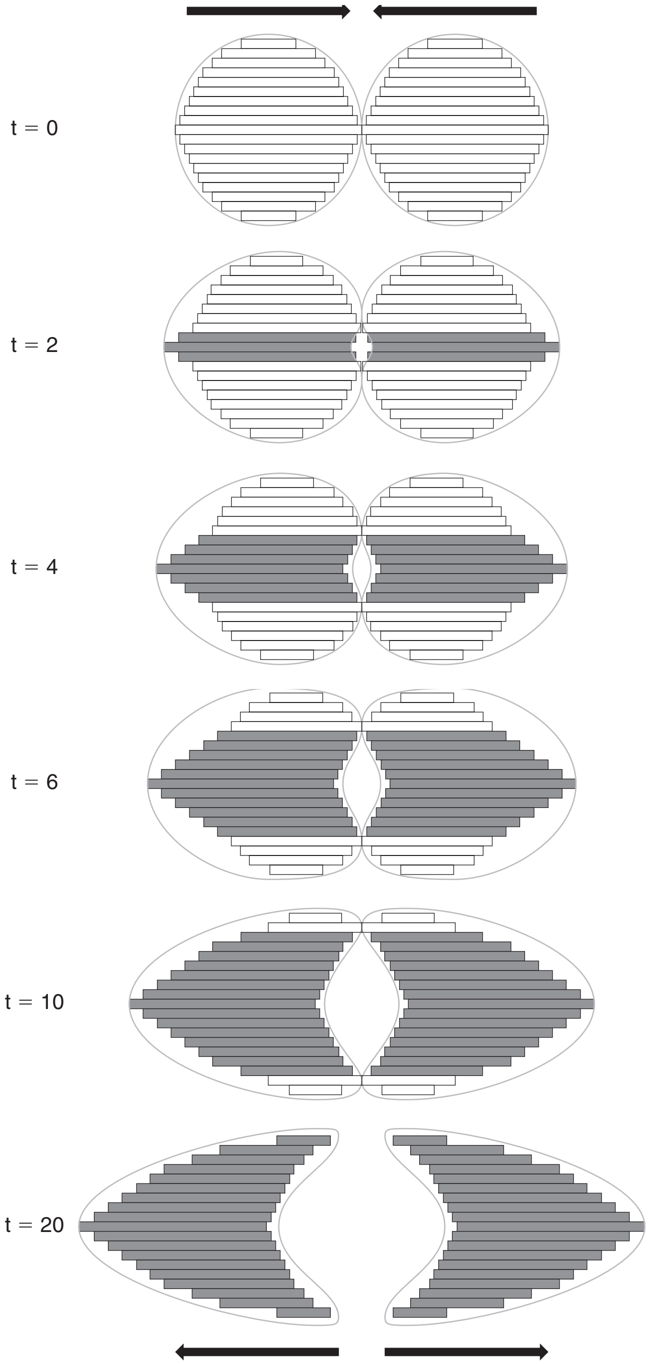

Figure 4.8 Reconstruction of the collision of two spheres made of homogeneous hard matter of the third kind according to Descartes' Impact Rule 1.

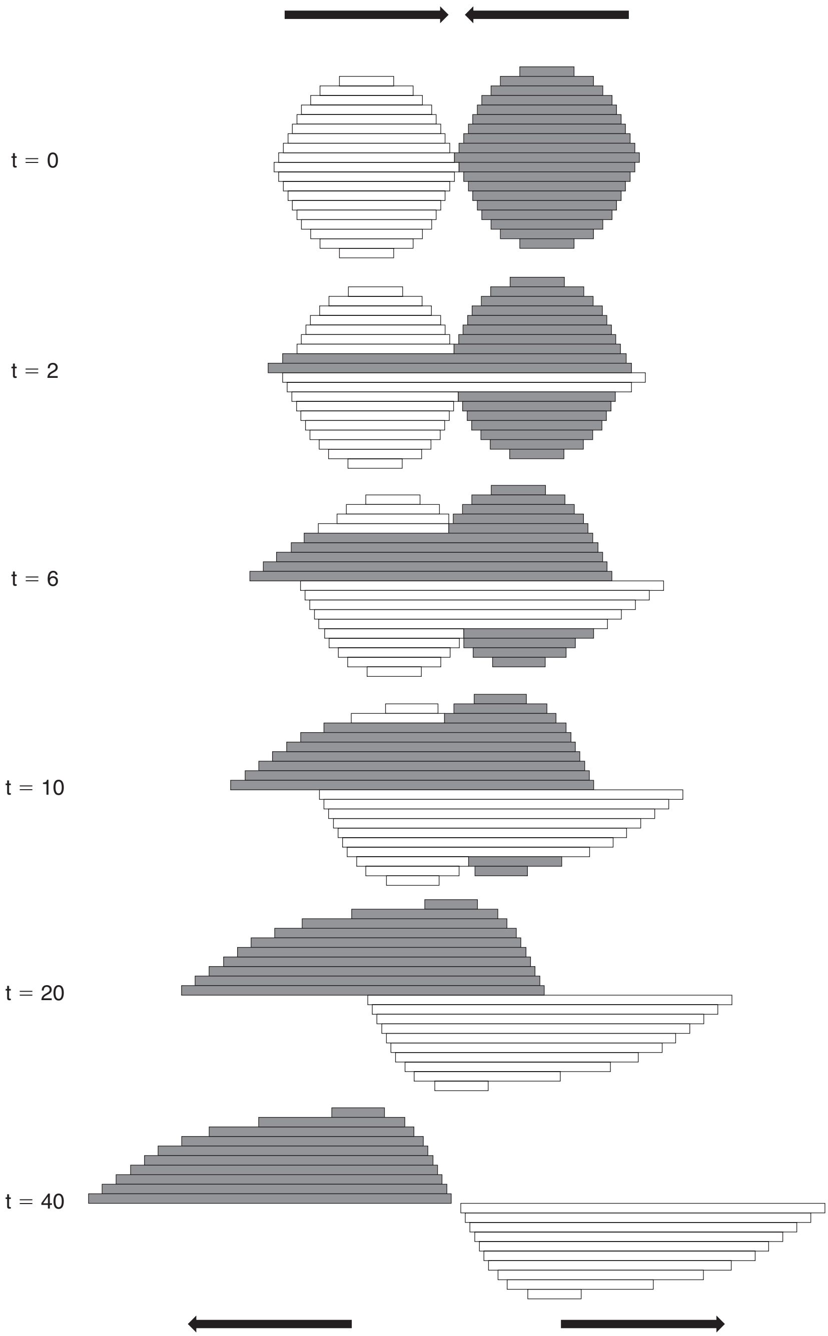

Figure 4.9 Reconstruction of a slightly off-centre collision of two spheres made of homogeneous hard matter of the third kind. This collision is actually two simultaneous collisions, each governed by Impact Rule 2.

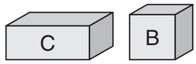

Figure 4.10 The picture of colliding bodies in the *Principia* (1644).

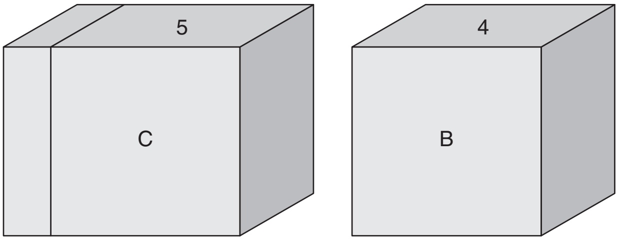

Figure 4.11 A picture of colliding bodies accompanying Descartes' letter to Clerselier of 17 Feb. 1645, published by Clerselier in his collection, *Lettres de M. Descartes* (Paris, 1657), 651; the reproduction in AT iv. 185 has B on the left and C on the right.

what occurs in idealized impact, according to Descartes. Figure 4.10 shows the picture that accompanies the impact rules in the *Principia*.[46] The paradigms of colliding bodies are cubes or boxes that do not have a *point* of collision like spheres but a *surface* of collision. When two bodies collide with their entire surfaces, then all the matter behind the surface in each body is involved in the interaction. In fact, only when the surface of collision is the *entire* front of the body, is the *entire* body even involved in an interaction. Thus the actual *size* of the body that collides with another is in effect only that part of the body that lies behind the actual surface of collision. Descartes' best representation of colliding bodies is to be found in the already cited letter to Clerselier written about a year after publication of the *Principia* (see Figure 4.11). Here, the two different-sized bodies have equal surfaces of collision; the larger body is merely *longer*. But these are just pictures – drawn by artists.[47] We want to take Descartes at his *word* and not just at his (printer's) pictures. We would hope that Descartes at least somewhere in his *Oeuvres* says that it is the *surface* of collision that counts. And, as a matter of fact, he does.

In one of the paragraphs elucidating the Third Law of Nature, Descartes analyses the factors relevant for determining which body in a collision has more force. The concrete question asked is: how much force can one body *apply* to another? Descartes here does not ask how much force in some general sense a body possesses, but 'what is the force of a body to act on another?' That is to say: how much (of the force it may possess) can a body actually bring to bear on a particular second body? And how is this to be measured?

> And this force should be measured not only by the size of the body in which it is and of the surface that separates this body from the other,

> but also by the speed of the motion and by the nature and [degree of] contrariety of the mode in which the different bodies encounter one another.[48]

Thus the relevant factors that must be taken into consideration when estimating how much punch a particular body can *deliver* to another body in a collision are:

1 the size of the body,
2 the size of the surface of collision,
3 the speed of the body,
4 the nature and degree of the opposition of modes: whether it is the *modes* of the bodies that are opposed or *the modes of these modes*, and whether this opposition is direct or intermediate (a *slow* motion is only gradually opposed to a *fast* motion; and *oblique* lines of determination are also only gradually opposed).

This passage confirms the fact that the surface of collision of bodies is dynamically relevant and must be considered when estimating the force of a body in collision. Thus the fact that Descartes' pictures show bodies with surfaces of collision is actually called for by the text. However, although the context of art. 43 makes it unequivocally clear that we are dealing with the interaction of two and only two bodies, and the Latin text itself makes it clear that the surface in question is only the surface *between* the two colliding bodies, most commentators have nonetheless interpreted this passage as making some vague reference to the *entire surface* area of the body, including its back and sides.[49] This would make no sense, however, especially since art. 45 specifies that the bodies in collision are considered to be dynamically isolated from the surrounding bodies. We are to assume that the two bodies are 'neither impeded nor assisted by any other surrounding bodies',[50] that is, that the other surfaces of the two colliding bodies are dynamically irrelevant for the ideal case.

This can be clarified by returning again to Rule 1 (and Rule 2) and citing their exact wording:

> First, if two such bodies, for instance, B and C, were completely equal [*plane aequalia*] and moved equally swiftly, B from right to left and C in a straight line from left to right, when they encountered one another, they would be reflected and afterwards continue to move, B towards the right and C towards the left, having lost none of their speed.[51]

Descartes stipulates in Rule 1 that the two colliding bodies are 'completely equal', that they have the same speed, and that the opposition of modes is confined to the determinations, which are directly opposed. Thus, in formulating this rule Descartes has taken all four factors mentioned in art. 43 into account in the same order in which they were listed – if, that is, we assume that by the *complete equality* of the bodies he means that they are equal both in volume and collision surface.[52] At any rate, according to Descartes' instructions, we must assume that there are no dynamically relevant differences in the collision surfaces; so we might as well take him to be heeding his own specifications – at least the Latin text allows and even suggests this.

Rule 2 takes up a case in which colliding body B is just a bit larger than C, but all other relevant circumstances are the same as in Rule 1:

> Secondly, if B were at all greater [*tantillo maius*] than C, everything else being posited as before, then only C would be reflected and both would move towards the left with the same speed.[53]

This rule clinches the case that the surface referred to in art. 43 is only the surface of collision. Whereas in Rule 1 the 'equality' of the two bodies might be taken to include the equality of their entire surfaces (and thus to apply also to spheres), this interpretation cannot be held for Rule 2. Descartes cannot here be referring to the *entire* surface of the body, since in that case 'everything else' would not be the same as before: if an oblong body B is increased in size, the surface of *collision* can under special circumstances remain the same, but the *overall* surface (in a sphere or any other regular figure) must *increase* in area if the size increases.

Summing up, we may say that the more literally we take Descartes *words* about the impact of bodies, the better they fit the pictures published under his name. In any case, without forces of cohesion, the simplest way to represent the quantity of matter involved in a collision is to picture two bodies whose surfaces of collision are equal and orthogonal to their directions of motion.

Notes

1 Much of the research presented here was originally conducted in cooperation with Gideon Freudenthal (Tel Aviv University), and some of it was published in the chapter we co-authored 'Conservation and contrariety' in Peter Damerow, Gideon Freudenthal, Peter McLaughlin and Jürgen Renn, *Exploring the Limits of Pre-classical Mechanics: A study of conceptual development in early modern science: Free fall and compound motion in the work of Descartes, Galileo, and Beeckman* (New York, 1992). An earlier version of this paper was read to the Colloquium 'Descartes: A Scientific Legacy of 400 Years,' Rio de Janeiro, Oct/Nov 1996.

2 See *Princ.* II art. 30; AT viii. 57: '*id omne quod reale est ac positivum in corporibus quae moventur*'.

3 *Princ.* II, art. 36; AT viii. 61–2.

4 G.W. Leibniz, *Leibnizens Mathematische Schriften*, ed C.I. Gerhardt (Berlin and Halle, 1849–63), vi. 117.

5 The conservation of *mv* was generally expressed as the assertion that the centre of gravity of the system was not affected by the collision. Both Christopher Wren and John Wallis (at least before they knew Huygens' work) derived their

impact rules from the immobility of the centre of gravity of the system and from the conservation of the 'sum' of the motions, that is, from the conservation of *mv* and |*mv*|. See Christopher Wren, 'Lex naturae de collisione corporum', *Philosophical Transactions of the Royal Society of London 4* (1669), 867–8 (also in: *The Correspondence of Henry Oldenburg, vol. 5,* ed. by A.R. and M.B. Hall (Madison, 1968), 319–21), and John Wallis, 'A Summary Account Given by Dr. John Wallis, of the General Laws of Motions', *Philosophical Transactions of the Royal Society of London 4* (1669), 864–6 (also in Hall, op. cit., 164–70).

6 See Max Planck, *Das Princip der Erhaltung der Energie* (Leipzig, 1913), 1.

7 Descartes' term for indicating the absence of interaction is *quantum in se est,* ('as far as in it lies') in the First Law, and *ex se ipso* and *seorsim spectatam* ('of itself' and 'considered separately') in the Second Law; see *Princ.* II art. 37 and art. 39; AT viii. 62–3. As a good metaphysician, Descartes prefers the positive formulation 'of its own accord' to the negative formulation 'in the absence of interactions': since interaction itself is not defined until the Third Law, the absence of interactions has no real meaning yet. Because the phrase, *quantum in se est,* is also used by Newton in his definition of inertia, there has been much speculation by historians of science on the origin of the phrase. See Volkmar Schüller, 'Die Bedeutung von "quantum in se est" in Newtons Principia', *NTM. Zeitschrift für Geschichte der Naturwissenschaft, Technik und Medizin* vol. 27 (1990), 11–23, for a discussion. Whatever the origins, the meaning is fairly clear: 'as far as the body in and of itself is concerned'.

8 *Princ.* II, art. 37; AT viii. 62.

9 *Princ.* II, art. 37; AT viii. 63.

10 Descartes could have been much more explicit about this principle. He does, however, use the concept of determination *three* times in art. 39 in discussing the Second Law (a fact reflected in none of the three available English translations of Descartes that include this section). This constitutes the decisive difference to the earlier formulation of this law in *Le Monde,* where the *word* 'determination' is repeatedly used in a quite different and non-technical sense (see AT xi. 45).

11 *Princ.* II, art. 39; AT viii. 63.

12 *Princ.* II, art. 40–52; AT viii. 65–70.

13 *Princ.* II, art. 40, AT viii. 65. Descartes goes on to qualify this statement, remarking that it applies to *corporeal* causes. Possible changes due to human or angelic minds are to be dealt with in another work; there is, however, no indication that such changes might be incompatible with the stated laws.

14 See *Princ.* III, art. 135 and II, art. 44; AT viii. 187 and 67. For discussion, see Damerow et al., op. cit., ch. 2.

15 It is not clear when the concept of determination crystallised for Descartes. It appears full-blown in the second chapter of the *Dioptrique*, where it is an essential part of the conceptual system from which Descartes derives the sine law of refraction, although it very certainly played no role in the original discovery. The concept is conspicuously lacking in *Le Monde*, although the *term* 'determination' does occur a number of times in contexts where the *concept* 'determination' later has a crucial technical use: in chs. 2, 7, and 13 (AT xi. 8–9; 45; 85). But at none of these places does 'determination' do any work for Descartes, and there is no reason to take it here as the technical term that it later becomes. However, in the later parts of the same manuscript, which presumably also postdate the beginning chapters and were published separately after Descartes' death as *De l'homme*, the concept itself seems to be used to deal with mind–body interaction (AT xi. 180, 185; 225–6). This development may have led Descartes to go back and make it a technical term in his optics. On the role of determination in mind–body interaction, see Peter McLaughlin, 'Descartes

on mind–body interaction and the conservation of motion', *Philosophical Review* vol. 102 (1993), 155–82.

16 AT vi. 94–5.

17 The parallelogram of motions was widely known through the pseudo-Aristotelian 'Mechanical Problems'; see Aristotle, *Mechanical Problems*, in *Minor Works*, trans. W. Hett (Cambridge, Mass., 1963). For literature and a brief review of the philosophical history of this rule, see the entry 'Parallelogramregel' in Jürgen Mittelstrass, ed., *Enzyklopädie Philosophie und Wissenschaftstheorie* (Stuttgart, 1980–96).

18 When Descartes on rare occasions speaks of compounding *motions*, he means arithmetical addition of scalar speeds. See, e.g., Descartes to Mydorge, 1 March 1638; AT ii. 20.

19 For a detailed presentation and discussion of the argument of the *Dioptrique* and the subsequent debates with Fermat and Hobbes, see Damerow et al., op. cit., 103–25 and 302–32 for a translation of the texts themselves.

20 See Damerow et al., ch. 2 for other examples from the period and for an explanation why Fermat's critique of Descartes does *not* dispute this assumption. The notion that the perpendicular to the surface is the line of (greatest) opposition and that orthogonal ('perfectly mixed') components combine without interference was completely undisputed. Perhaps the best illustration of the use of contrary oppositions in this sense, because of its dogmatic textbook presentation, is Marcus Marci's *De proportione motus* (Prague, 1639).

21 Descartes to Mersenne for Fermat, 15 Oct 1637: AT i. 452.

22 The logical relation of determinations to motions is best explained by Descartes in letters to Mersenne, for Hobbes (21 April, 1641) and for Bourdin (29 July, 1640): AT iii. 354–6 and 111–13.

23 See Descartes' letter to Mersenne for Hobbes of 21 April 1641; AT iii. 354–6. Descartes himself mentions only one component of the determination of being Socrates.

24 A.I. Sabra, *Theories of Light from Descartes to Newton* (London, 1967), ch. 4, provides the classical analysis of Fermat's critique. See Damerow et al., op. cit., 115–17 for minor but consequential amendments to this analysis.

25 This is the line Fermat takes in his first letter criticising the *Dioptrique* (April or May 1637; AT i. 354–63).

26 This is the line Fermat takes in his second letter criticising the *Dioptrique* (Nov. 1637; AT i. 463–74).

27 3 Dec. 1640; AT iii. 251.

28 Alan Gabbey, 'Force and inertia in the Seventeenth Century: Descartes and Newton', in Stephen Gaukroger, ed., *Descartes, Philosophy, Mathematics, and Physics* (Sussex 1980), 230–320: 259.

29 See Damerow et al., op. cit., ch. 2.

30 See, e.g., Richard S. Westfall, *Force in Newton's Physics: The Science of Dynamics in the Seventeenth Century* (London, 1971), 65; Gary Hatfield, 'Force (God) in Descartes' physics', *Studies in History and Philosophy of Science* vol. 10 (1979), 113–40: 118; and Daniel Garber, *Descartes' Metaphysical Physics* (Chicago, 1992), 351–2.

31 1 March 1638; AT ii. 17–18; my italics.

32 29 July 1640; AT iii. 113; my italics.

33 This way of representing refraction makes the relation of the sines AH and HF more perspicuous. Historical evidence suggests that Descartes like others originally worked with an altered radius and discovered the law of refraction as a relation between two radii (cosecants). See John Schuster, *Descartes and the Scientific Revolution, 1618–1634: An Interpretation* (diss., Princeton University, 1977), 268–368.

34 *Princ.* II, art. 40; AT viii. 65.
35 *Princ.* II, art. 44; AT viii. 67.
36 Descartes presented a case of oblique collision in a letter to Mersenne (26 April 1643) in a way compatible with his impact rules. See AT iii. 648–52; for an analysis of this case, see Damerow et al., op. cit., 120–3.
37 For a detailed analysis of the impact rules, see Damerow et al., 91–103. The impact rules, long an embarrassment to Cartesian scholars and normally even left out of translations, have been subjected to a number of enlightening analyses in recent years; see Gabbey, op. cit.; Desmond M. Clarke, 'The impact rules of Descartes' physics,' *Isis* vol. 68 (1977), 55–66; Garber, op. cit., 231–62; and Dennis Des Chene, *Physiologia. Natural Philosophy in Late Aristotelian and Cartesian Thought* (Ithaca, 1996), 286–312.
38 This holds for Galileo, Marci, Digby, Hobbes, Wren, and Wallis. See Martin Kalmar, *Some Collision Theories of the Seventeenth Century: Mathematicism vs. Mathematical Physics* (diss., John Hopkins University, 1981), and Westfall, op. cit. Compare one of Digby's formulations of the chief principle of mechanics: 'And so much velocity in proportion, will recompense so much gravity'. (Kenelm Digby, *Two Treatises* (Paris, 1644), 66).
39 17 Feb. 1645; AT iv. 185–6. Spinoza argued that this principle directly follows from the First Law; see *Renati Des Cartes Principiorum Philosophiae Pars I & II*, bk. II, §25. The somewhat unusual terminological distinction between *mouvement* and *motion* (in French) may be derived from the distinction between *motus* and *motio* in the Latin version of the pseudo-Aristotelian *Mechanical Problems*.
40 See Gabbey, op. cit.
41 Des Chene, op. cit., 286–312, stresses the importance of integrity and absorption in the impact rules.
42 Letter to Mersenne for Hobbes, 21 Jan. 1641; AT iii. 289.
43 This last case is presented only in the French translation of the *Principia* (AT ixB. 92), which also seems at least to contemplate the completely trivial case in which the overtaking body B is both faster and larger than C.
44 Marcus Marci (op. cit.), on the other hand, actually illustrates one of his discussions of impact with the picture of a billiard table.
45 *Princ.* II, art. 55; AT viii. 71.
46 *Princ.* II, art. 46; AT viii. 68. The French *Principes* has the mirror image of the same picture.
47 Letter to Clerselier, 17 Feb. 1645. The picture is taken from Clerselier's edition of Descartes' correspondence – *Lettres de Mr Descartes. où sont traittées les plus belles questions de la morale, physique, medicine, et des mathematiques* (Paris, 1657), 651 – which was published only after Descartes death; the original manuscript is unknown (AT iv. 185 transposes bodies B and C). Even in his own publications Descartes did not always carefully check the drawings and was not unwilling to blame the printer for the failings of drawings when it suited his purposes; see, e.g., AT iii. 357.
48 *Princ.* II art. 43; AT viii. 67.
49 This has even led them to mistranslate the passage to fit the interpretation. The Latin reads: '*Visque illa debet aestimari tum a magnitudine corporis in quo est, et superficiei secundum quam istud corpus ab alio disjungitur; tum a celeritate motus, ac natura et contraritate modi, quo diversa corpora sibi mutuo occurunt.*' The key phrase is *ab alio*; Descartes speaks of the surface that separates the colliding body from *the other body*. All three published English translations have Descartes talk about the surface that separates a body from all the surrounding bodies, not just from the one it hits. See *Descartes, Philosophical Writings*, ed. and trans. by E. Anscombe and P.T. Geach (Edinburgh, 1964); *Principles of Philosophy*, trans. V.R. and R.P. Miller (Dordrecht, 1983); *The Philosophical Writings of Descartes*,

3 vols., trans. J. Cottingham, R. Stoothoff, D. Murdoch, A. Kenny (Cambridge, 1985–91), as well as almost every commentator on the subject. The French translation of the phrase (‘*separé d'un autre*’) has been cited in support of the usual interpretation, e.g., by Pierre Costabel, ‘Essai critique sur quelques concepts de la mécanique cartésienne’, *Archives internationales d'histoire des sciences* vol. 20 (1967), 235–52. There are other passages in the *Principia, Le Monde,* and an often cited letter to de Beaune on ‘natural inertia’ (AT ii. 543–4), where Descartes also deals with the physical significance of the surface of a body, and may be interpreted to mean more than just the front end. But how much of the surface is significant depends on how much is involved in interactions: the dynamically relevant cross-section.

50 AT viii. 67.

51 *Princ.* II, art. 46; AT viii. 68.

52 Most scholars take Descartes to be referring to size only, either explicitly (as do the translations of Miller and Miller, op. cit., 64, and Cottingham, op. cit., 244) or implicitly (e.g. Garber, op. cit., 256, following Picot's French translation) by translating *plane aequalia* not as ‘*completely* equal’ but as ‘*exactly* equal’, so as to contrast with the ‘slightly larger’ (*tantillo maius*) in size of Rule 2.

53 *Princ.* II, art. 47; AT viii. 68.

5 A different Descartes

Descartes and the programme for a mathematical physics in his correspondence

Daniel Garber

The seventeenth century was the period in which mathematical physics as we know it was invented, in which figures like Galileo, Huygens, and Newton learned to apply mathematics to physical problems. Descartes would seem to have been well placed to participate in this important movement of thought. He was one of the pre-eminent mathematicians of the century, and his *Géometrie* one of the great works in the history of mathematics. He wrote extensively on questions in physics, and his mechanistic vision of the world was deeply influential on his contemporaries, perhaps even more so than even his metaphysics. Indeed, his identification of body and extension would seem to guarantee that he would have to be a mathematical physicist; for him, bodies are just the objects of geometry made concrete. It is not surprising, then, that any number of times he declared that his physics is just mathematics. For example, in the *Principia*, Descartes writes:

> The only principles which I accept, or require, in physics are those of geometry and pure mathematics; these principles explain all natural phenomena, and enable us to provide quite certain demonstrations regarding them.[1]

Similarly, in a letter to Mersenne, 11 March 1640 he writes:

> I would think I knew nothing in physics if I could say only how things could be, without demonstrating that they could not be otherwise. This is perfectly possible once one has reduced physics to the laws of mathematics. I think I can do it for the small area to which my knowledge extends.[2]

But despite all of this, and despite his boasts, it seems that Descartes never managed to put these two domains together. In radical contrast to his approximate contemporary Galileo, for example, Descartes' mature physics is almost entirely qualitative. There is, of course, serious mathematical reasoning in Descartes' optical writings, in the *Dioptrique* and in the *Météores*, where he discusses topics like reflection, refraction, and the rainbow, branches of what was called mixed mathematics at the time. One also finds serious mathematical reasoning in Descartes' early fragments, particularly the writings he did for Isaac Beeckman and in the years following. But in *Le Monde* and the later *Principia*, there is hardly a calculation, an equation or a geometrical demonstration to be seen.

Take the development of his physics in *Principia* Parts II to IV. Descartes' basic conservation law is, at root, quantitative: conservation of size × speed. But it is not given quantitatively in the text, nor is it explicitly invoked in any kind of quantitative way in the passages that follow. Descartes gives a version of what later came to be called the law of inertia: a body in uniform rectilinear motion will remain in uniform rectilinear motion, unless interfered with by some outside body. From this Descartes derives centrifugal force, and argues that a stone turned in a sling will tend to depart from the sling. This centrifugal force is basic to the theory of vortices that is at the centre of his cosmology in Part III of the *Principia*. According to that theory, the world sorts itself out into sworls of fluid that carry the planets around with them, around a central sun. Light, on this theory, is simply interpreted as the pressure of the sworling fluid, the centrifugal force of the subtle matter. But Descartes nowhere attempts to quantify this, to give a mathematical expression to the pressure, to say anything about the speed the fluid must have to result in the phenomena that we observe, to say anything about the paths of the planets. His cosmology is entirely qualitative, as was his discussion of the Copernican, Ptolemaic, and Tychonic cosmology earlier in Part II. Finally, there is his discussion of the magnet in Part IV of the *Principia*. Descartes gives an account of magnetic phenomena in terms of tiny screw-shaped particles whose motion through pores in lode stones is supposed to explain magnetic attraction and repulsion. There is no attempt at all to say anything quantitative about the force of attraction or repulsion. Alexandre Koyré put it succinctly: 'The fact is well-known. Descartes' physics, as presented in the *Principia*, contains no expressible mathematical laws. It is, in fact, as little mathematical as that of Aristotle.'[3] Descartes' physics can be read like a novel, as he suggested to the Princess Elisabeth: there are elegant diagrams, and beautiful images, but not one single equation or geometrical argument. The physics of the *Principia* is all words.

This, in any case, is the conventional wisdom, what most commentators believe about Descartes. But the correspondence gives us quite a different picture of Descartes. In his correspondence, particularly his correspondence with Mersenne, one finds a physicist quite capable of participating in the programme for a mathematical physics. It is this different Descartes that I would like to explore in this essay.

Physico-mathematici paucissimi: mathematical physics and the Galilean paradigm

Before turning to Descartes, however, I would like briefly to discuss mathematics, physics, and their relations in the early seventeenth century, when Descartes first comes onto the scene. In his notebooks, Isaac Beeckman notes, with pride, that Descartes found him unusual in his ability to join mathematics with physics, in a passage entitled '*Physico-mathematici paucissimi*'.[4] Descartes obviously meant this to be a compliment, and Beeckman took it as such. What did he mean here?

It is well known that Aristotelian natural philosophy had an ambiguous relation to mathematics. Strictly speaking, for the orthodox Aristotelian, mathematics has no real place in natural philosophy (physics); mathematics deals with abstractions, not the real natures of things and their causes as they are in the world, the subject matter of physics. On the other hand, there is a long tradition of what was called mixed mathematics. This included disciplines such as astronomy, optics, and music, areas in which mathematical methods were used on questions that are connected to objects in the physical world. Characteristically, though, there was a difference between a (mixed) mathematical treatment of a domain, and a physical treatment. In astronomy, for example, the mathematician treated the apparent motions of the planets, building mathematical models based on past experience to predict future phenomena, while the natural philosopher dealt with the nature of celestial matter, the real cause of motion, etc. The mathematical astronomer was interested in saving appearances, while the physicist was interested in knowing the true story.

The term 'physico-mathematics' was widespread in the early seventeenth century.[5] Sometimes it seemed to mean simply a work in mixed mathematics in the traditional sense.[6] At other times it seems to designate a work that includes both discussions of mixed mathematics and (separate) discussions of the nature and causes of things in the world.[7] In its most interesting use, however, it was the attempt to extend the kinds of mathematical methods at use in the different branches of mixed mathematics to other areas more traditionally treated in physics proper. This, I think, is what Beeckman had in mind.

While a number of people attempted to combine mathematics and physics in this period, one programme was particularly important in the early seventeenth century. Galileo's work from the 1620s and 1630s (and even earlier) shows a very sophisticated sense of how to take problems in the physics of heavy bodies in motion, and subject them to mathematical treatment. Using a variety of experiments, Galileo was able to show how for a body in free fall, the distance fallen is proportional to the square of the time. He was also able to extend these investigations in a number of very fruitful ways, to the behaviour of balls on inclined planes and to the behaviour of pendula. Most impressive to his contemporaries were his studies of projectile motion. Combining a uniform horizontal motion with a uniformly accelerated vertical motion, he was able to show that a projectile moves in a parabolic path (see Figure 5.1[8]). In these studies, Galileo put forward a very powerful and persuasive paradigm for understanding how mathematics could be applied in physics, a model for how to do the new physics. This is what I shall call the Galilean paradigm.[9] The Galilean paradigm has its main domain of application in the physics of heavy bodies, bodies with a 'natural tendency' to fall towards the centre of the earth. It makes use of certain laws (what later came to be called the law of inertia – every body continues in uniform rectilinear motion unless interfered with – as well as the Galilean law of free fall), grounded in observation, as well as reasoning borrowed from mechanics (the science of simple machines like the inclined plane and the lever) to give mathematical accounts of the behaviour of heavy bodies in a variety of situations. The Galilean paradigm is not the exclusive work of Galileo; it clearly contains elements, including the science of mechanics itself, that can be traced back to Archimedes, the pseudo-Aristotelian *Mechanica*, and a variety of sixteenth-century writers.[10] But in the early seventeenth century, it was Galileo who best personified this new spirit in physics.

Prominent among those who participated in this programme was Father Marin Mersenne, Descartes' close friend and intellectual sponsor. From the time he first came into contact with Galileo and his ideas in the mid-1620s, Mersenne was deeply affected by his approach to the study of motion.[11] While he did not always agree with Galileo, Mersenne published French editions of his writings, gave expositions of Galileo's ideas in his own work, and fully absorbed his style of physico-mathematics. In 1634, shortly after Galileo's condemnation in Rome, Mersenne published in Paris a book entitled *Les méchaniques de Galilée*, a translation (with Mersenne's expansions and commentaries) of a then unpublished manuscript on the mathematical theory of simple machines and percussion, now known under the title *Le meccaniche*. This was followed in 1639/1640 by the publication in Paris of *Les nouvelles pensées de Galilée*, a similarly free

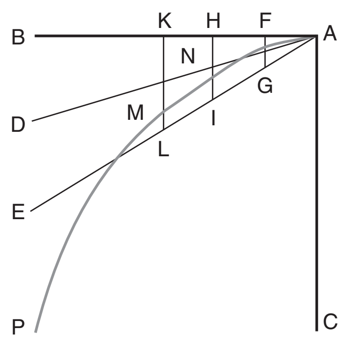

Figure 5.1

French adaptation of Galileo's *Discorsi e dimostrazioni mathematiche intorno a duo nuove scienze* (Leiden, 1638). The Galilean paradigm in the study of heavy bodies in motion also deeply penetrated Mersenne's own writings, including the *Harmonie Universelle* (Paris, 1636/37), the *Cogitata Physico Mathematica* (Paris, 1644), and the *Novarum observationum, Tomus III* (Paris, 1647).

The treatment of Galileo in the *Harmonie Universelle* is indicative of Mersenne's infatuation with Galileo.[12] The main subject of the *Harmonie Universelle* is music, of course, a traditional branch of mixed mathematics. But the *Harmonie Universelle* begins with a treatise on sound, its nature and properties, which includes extensive discussions of motion in general. Immediately after the table of contents, Mersenne gives in summary eight theorems of Galileo on the free fall of heavy bodies and the motion of heavy bodies down an inclined plane, *'mouvemens naturels des corps pesans'*. Book II, then, is about *'Des mouvemens de toutes sortes de corps'*. It is in this book that the influence of Galileo's mathematical treatment of the motion of heavy bodies is most salient. Here Mersenne deals in detail with free fall, motions composed of free fall and the rotation of the earth, inclined planes, whether a body in free fall always increases in speed, the motion of pendula, among many other things. At the very end of the *Harmonie Universelle* there is a section entitled *'Nouvelles Observations Physiques et Mathematiques'*, in which Mersenne discusses the free fall of heavy bodies in air and water, the composition of violent and natural motions, and the heaviness of bodies at different distances from the centre of the earth. All of these discussions show Mersenne's attempts to extend the mathematical methods of the mixed sciences to the understanding of the motion of heavy bodies, a programme that for Mersenne, is clearly under the direct influence of Galileo.

But there was another important participant in the Galilean programme in this period, one whose writings in this area are less well known than Mersenne's, though no less important: René Descartes.

Descartes, Mersenne, and physico-mathematics

In his letters to Descartes in the late 1630s and early 1640s, Mersenne presses many of the very issues that are of concern to him in the writings of this period, issues very much connected with the new mathematical physics in the Galilean style that he was then working out. And Descartes replies in kind. It is in these exchanges that we see a very different Descartes. While there are many instances of this that we might discuss, I would like to call attention to one particular example.

In the *Harmonie Universelle,* Mersenne had raised the question as to whether a body weighs more or less as it is farther from or closer to the centre of the earth.[13] This was a question that much interested Mersenne, as well as many of his contemporaries.[14] In response to this query, Descartes sent Mersenne on 13 July 1638 a letter that amounts to a short treatise on the subject, broadly in the Galilean style of argument.[15] After a long discussion of the nature of gravity (which he there considers an empirical question), Descartes sets aside the physical discussion of the causes of gravity, and turns to a mathematical treatment of the question in Galilean style: *'Ie passe maintenant aux raisons mathematiques . . .'*, he writes.[16] One can only present such a mathematical treatment, though, on the assumption of certain physical facts about the world, facts about the nature of gravity and how it works.[17] And so, Descartes writes:

> We shall suppose that each particle of a given heavy body always has a given force or tendency to descend, whether it is far from the centre of the earth or close to it, and no matter how it is situated. As I have already remarked, this assumption is perhaps not true; yet we ought to make it nevertheless, in order to facilitate the calculation. In a similar way astronomers assume that the average motions of the stars are regular [*égaux*], in order to make it easier to calculate the true motions, which are irregular.[18]

It is on this assumption about heaviness that Descartes bases the rest of his discussion in the letter. This is what he then takes himself to demonstrate:

> Now given the assumption of the equality of absolute heaviness, we can demonstrate that the relative heaviness of all hard bodies . . . is somewhat less when closer to the centre of the earth than when further from it.[19]

The sort of relative heaviness at issue here and in the rest of the letter is not the sort that Descartes had discussed earlier in the letter, where what is at issue is internal versus external causes of the tendency a body has to move towards the centre of the earth. Rather, what he will discuss is the notion of heaviness as it appears in statics. For example, in statics, we can ask how much weight is necessary to keep a body from rolling down an inclined plane of a particular inclination, or how much weight is necessary to support a given body held up by a particular system of pulleys. One might say that since it takes a smaller weight to support a body on one inclined plane, than on another that makes a greater angle with respect to the horizon, the same body has a smaller 'relative weight' in the one case than in the other.[20] This is the notion of relative weight that concerns Descartes in what follows. His claim, then, is that the relative weight of a body in this sense is less as the body approaches the centre of the earth.

Let us begin by considering Descartes' discussion of the inclined plane in the letter.[21] He begins by reviewing what is normally said about the inclined plane. (see Figure 5.2). He writes:

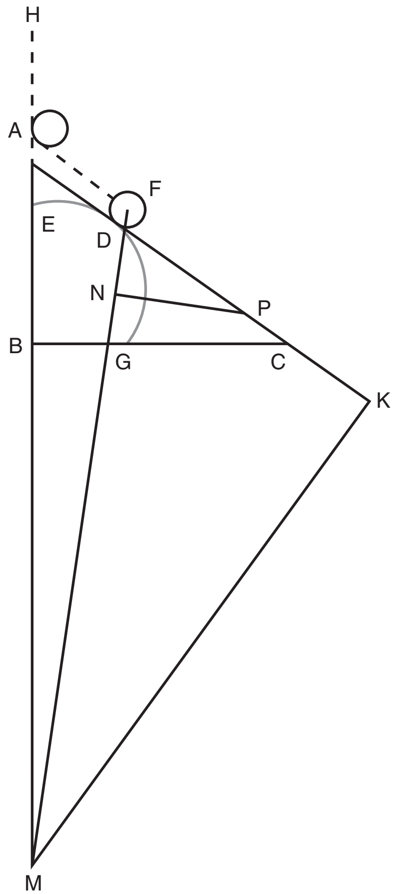

Figure 5.2

> All who write on mechanics are agreed that the heaviness of weight F, insofar as it is resting on plane AC, is in the same ratio to its absolute heaviness as line AB is to line AC, so that if AC is twice as long as AB, and F weighs 200 pounds in the open air, it will weigh only 100 pounds relative to the power H which draws it or supports it on plane AC.[22]

But, Descartes notes, this calculation is based on an idealization. If we take BC and AC to be genuinely straight lines, then Descartes argues, we must assume that heavy bodies tend downwards in parallel lines, which, of course, is strictly speaking false. It is the very fact that when we take account of the fact that the earth is a sphere, a genuinely straight inclined plane does not make a constant angle with respect to the true vertical, the line connecting it to the centre of the earth that is the basis of Descartes' argument in what follows (Figure 5.2). Let us assume that the heavy body F tends towards the centre of the earth M, and that the plane AC is a genuinely straight line. Descartes writes:

> On the assumption that the surface AC is perfectly flat, the ratio between the relative heaviness of the weight F and its absolute heaviness will not be the same as the ratio between line AB and line AC, except when it is right at the top A; for when the weight is just a little lower down, at D or C, for example, the ratio will be a little less.[23]

Why is this so? At any given point of the plane, the true vertical, the direction that the body would fall if it were released, is the line connecting that point to the centre of the Earth. Similarly, the true horizontal would be that which is perpendicular to the true vertical. Now, in the diagram, the closer F gets to K, the angle it makes with respect to the true vertical is closer and closer to a right angle. That is, the closer the chosen place gets to K, the closer we are to a horizontal plane. And the closer the plane is to horizontal, the less weight is necessary to hold a body on it.

This demonstration is the basis of Descartes' answer to the question (see Figure 5.3). Consider the rigid heavy body BCD descending from H through F towards A, the centre of the earth. Because the body is rigid, the part of the body nearest D is constrained to move along the line DdG and the part nearest B along BbE. In this way, Descartes suggests, we can think of B and D as weights moving along straight inclined planes BbE and DdG. Then, by the reasoning above, it should take less weight to hold those parts in equilibrium the closer they are to the centre of the earth, A. This reasoning can be repeated for every part of the body between B and C and between D and C. Since the only part of the body for which this reasoning does not work is the centre, the line going through the body at C, this is true of the whole body. So, Descartes concludes:

Consequently the whole body weighs less when closer to the centre of the earth than when further from it, which is the point that was to be demonstrated.[24]

(Immediately after giving this demonstration, he goes on to give another demonstration,[25] using his observations on the lever, in which he shows another sense in which a body closer to the earth weighs more than it does when further from the earth!)[26]

Mersenne was very impressed. After receiving Descartes' long letter, he asked if he could publish it, perhaps thinking of including it in one of his own collections, just as he had published Roberval's *Traité de mechanique* in the *Harmonie Universelle*. In his *Cogitata physico mathematica* of 1644, Mersenne published substantial excerpts of Descartes' letter in translation/paraphrase, as well as many other excerpts from his correspondence with Descartes on similar subjects.[27]

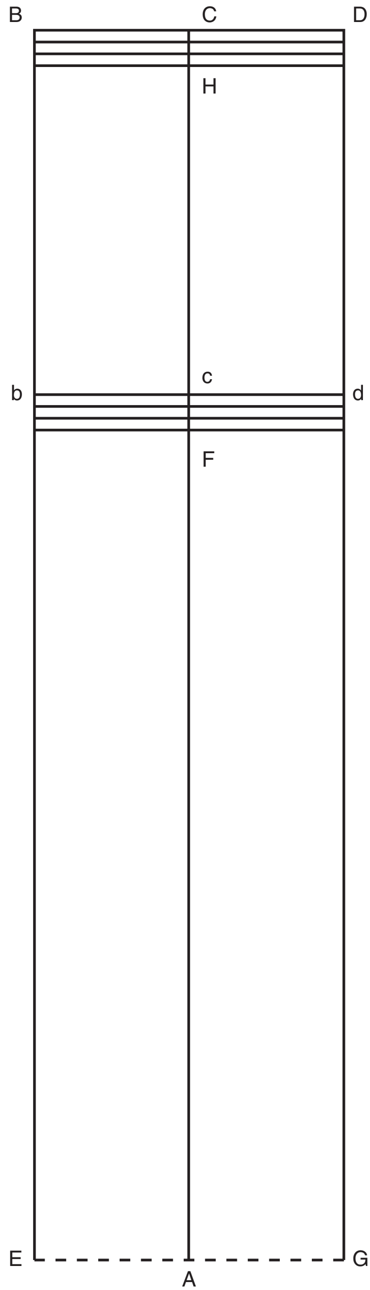

Figure 5.3

Mersenne's writings often contained presentations of the work of others, so, in a sense, this was hardly unusual. But, at the same time, it is striking to compare the letters that Descartes wrote to Mersenne in the late 1630s and the early 1640s, with Mersenne's *Cogitata*. These letters are, in a sense, sketches for Mersenne's published writings, and it is only a slight exaggeration to say that Descartes is a collaborator on them, a silent co-author. In this way, one can see Mersenne's *Cogitata* as one of Descartes' anonymous publications, the mathematical physics that he never published under his own name. In this context we see a Descartes who is very much a part of the circle of mathematical physicists working in France and Italy at that time, and following the Galilean paradigm for combining mathematics and the physics of heavy bodies.

But, at the same time, we cannot ignore the significance of the fact that Descartes did not take public credit for this work. Mersenne, of course, asked Descartes permission to publish these excerpts from their correspondence. Descartes gave him permission, but only as long as he did not directly attribute it to him (*pourvû que mon nom n'y soit point mis*[28]). Descartes was not ashamed of his work, but, at the same time, he did not want it associated with his name. When Mersenne published it, it was attributed only to a '*clarissimus vir*' or an '*illustris vir*'. Even though Descartes was happy to discuss these issues with Mersenne in correspondence, he did not want his name attached to them in public. And even though he allowed Mersenne to publish this work, Descartes himself did not. It is very curious that Descartes, who himself published a fair amount, never saw fit to address in public the kinds of questions in physico-mathematics that fill his correspondence with Mersenne. Why?

Descartes and the Galilean physics of heavy bodies

To answer this last question, let me return to the Galilean paradigm for doing mathematical physics. As I have argued, it was the most influential paradigm for doing mathematical physics in the early seventeenth century; it would not be until the end of the century when physicists would find another paradigm for mathematical physics as powerful as Galileo's in the work of Isaac Newton. Basic to the Galilean paradigm is the assumption that heavy bodies have a natural tendency to fall towards the centre of the earth, and that they do so in such a way that equal increments of speed are added in equal times. Once we have this assumption (and a few others), then the programme is off the ground; making this assumption, we can begin to treat free fall, inclined planes, pendula, in the sophisticated mathematical ways that are characteristic of the Galilean paradigm.

Now, it is often said that for Descartes, the applicability of mathematics to physics is a consequence of the fact that geometrical extension is the essence of body. But, ironically, it is the very identification of matter and extension that makes it impossible for Descartes to accept the assumptions characteristically made in the Galilean paradigm. Because they contain nothing over and above extension, bodies can have no innate tendencies at all; in particular, bodies, in and of themselves, have no tendency to fall to the centre of the earth – or towards any other particular place. Taken by themselves, bodies tend to remain in motion while they are in motion, and remain at rest while they are at rest, but have no tendencies to move in any particular direction. Gravity, the tendency to fall towards the centre of the earth, is explained for Descartes in terms of the interaction between a body and the vortex of subtle matter that turns around the earth. Strictly speaking, bodies are pushed towards the centre of the earth by colliding with the particles of subtle matter in the vortex.

Thus, Descartes argues, the assumptions about heavy bodies embodied in the Galilean paradigm are simply wrong. Bodies do not, as such, tend to fall towards the centre of the earth. One can assume that they do, and that they maintain the same absolute tendency to fall however far they might be from that centre, but this assumption is simply false. And because Descartes thinks that gravity is due to the collision between a so-called heavy body and the particles of the subtle matter, the Galilean laws of free fall are quite simply false. Descartes wrote to Mersenne, 11 March 1640:

> At the first moment of a body's descent, it is pushed by the subtle matter, which gives it one degree of speed; then at the second moment, it pushes it a bit less, and gives it again almost a degree of speed, and so on. This results in a speed that is almost in proportion to the square of the time of descent, at the beginning of the descent. But this proportion is entirely lost when they have descended several feet [*toise* – about two metres], and the speed does not increase any more, or almost not at all.[29]

Bodies in free fall will not continually accelerate, as the Galilean law implies. They will accelerate at first, when they begin to fall, and for a short period, Galileo's law of free fall will hold, but when they reach a certain speed, a function of the speed of the particles in the vortex, they will accelerate less quickly, and eventually fall at a constant speed.

Descartes is quite willing to work within the Galilean paradigm, when Mersenne asks him to. But until the true cause of gravity is properly established, such work is a kind of game for him, not real physics, but a mere exercise in pure mathematics. If we assume that bodies fall in accordance with Galileo's law, then we can derive a parabolic path for projectile motion:

> If we assume this, then it is very easy to conclude that the motion of projectiles should follow a parabolic line; but these assumptions being false, his conclusion may also be quite far from the truth.[30]

Similarly, when treating the problem of the heaviness of bodies as they get closer to the centre of the earth in a mathematical way, Descartes has to make assumptions 'in order to facilitate the calculation', even though those assumptions are known to be false.[31] But the answer you get, in the end, is only as good as the assumptions that you make in the beginning. Because Descartes does not think that the assumptions are very good, the final result is not, either.

In this way, Descartes' refusal to publish his exercises in mathematical physics in his own name was not a rejection of the enterprise for a mathematical physics, but simply a substantive criticism of what I have called the Galilean paradigm.[32] Koyré characterizes the difference in temperament between Descartes and Galileo as follows:

> The thought, or, if you prefer, the mental attitude of Galileo differs sensibly from that of Descartes. It isn't purely mathematical; it is physico-mathematical. Galileo does not advance hypotheses concerning the possible ways accelerated motion might be; what he seeks is the real way, the way that nature makes use of.[33]

I think that Koyré has got this almost exactly wrong, at least from Descartes' point of view. What Descartes seeks is a physics grounded in a true comprehension of nature as it really is, and a true knowledge of the causes underlying phenomena. On his view, Galileo's mathematical physics of motion is a mathematical fantasy, grounded in arbitrary assumptions, '*un roman de la nature*', no less fanciful for being expressed in mathematical language. What Descartes wanted was a genuine physico-mathematics, as much physics as it is mathematics: a mathematical science of motion that involves knowledge of the real cause of the effects. It is only when we know the real causes of gravity that we will have a true science of the motion of heavy bodies.

For that reason, Descartes the Galilean physicist of the correspondence with Mersenne preferred to remain hidden behind a mask of anonymity. Once again, *'larvatus prodit'*, he goes forth masked.

A Cartesian paradigm for mathematical physics?

So far we have concentrated on Descartes' reaction to the Galilean paradigm for the physics of heavy bodies, and why he did not want to follow it. A deeper question still remains. Even though Descartes rejected Galileo's way of making the physics of heavy bodies mathematical, one might ask, then, why did Descartes not substitute his own programme? Part of the explanation may be that the physics of heavy bodies was simply not very important to Descartes, certainly not as important as it was to Galileo. This is certainly true but, nevertheless, the behaviour of bodies in vortices of subtle matter was central to Descartes, and the behaviour of heavy bodies near the earth is just a special case of that for Descartes. And while vortices and the motion of bodies in vortices are quite prominent in the *Principia*, his account there is, as we have said earlier, entirely qualitative.

Descartes certainly tried to produce a mathematical account of heavy bodies and their behaviour in vortices. One can see a very serious attempt at creating a mathematical physics of heavy bodies in the writings from Descartes' earliest years, as preserved in Beeckman's notes from late 1618 and some of Descartes' papers probably from the same period. There Descartes treats, for example, the problem of free fall that is at the centre of the Galilean paradigm, using the same assumption that Galileo did, that falling bodies are uniformly accelerated. He treats it badly, perhaps, and falls into paralogism, but he treats it no worse than the young Galileo did. Later, after coming upon his conception of the cause of gravity, he seems to approach the problem of the mathematical law governing free fall in a different way. Early in 1631, at work on *Le Monde*, he wrote to Mersenne: 'I think that I could now determine the rate at which the speed of a falling body increases, not only in a vacuum, but also in real air'.[34] This suggests that he was attempting to work out the laws governing falling bodies as they actually behave in this world, as they move towards the centre of the earth due to collisions with particles of subtle matter. Among the notes that Leibniz preserved from the 1630s, there is at least one text that deals with exactly this question.[35]

But why do none of these thoughts about heavy bodies appear in his published writings? Why did he not succeed at offering an alternative to the Galilean paradigm? There has been a temptation to see this as a result of some profound lack of vision in Descartes, an inability to see what Galileo and others saw, how mathematics can function in a physical theory. Paul Tannery, for example, argues that Descartes' failure is a consequence of the fact that 'he lacked a sense of the conditions of the application of mathematics to questions other than numbers, shapes, and geometrical magnitudes, a sense that, on the contrary, Galileo possessed to the highest degree'.[36] This cannot be quite right, however. As I pointed out earlier, through Mersenne Descartes was very much a participant in the Galilean physics of his day, though he chose not to be such publicly under his own name; it was a game he could play, but chose not to. This suggests that the reasons for his failure to make his own physics mathematical lie elsewhere.

Part of the reason is, perhaps, the complexity of the problems he faced, given his views about the nature of the world. On Descartes' conception of heaviness, a heavy body falls because it is pushed towards the centre of the earth by virtue of the collision between the body in question and the individual particles in the vortex surrounding the earth. As a number of other writers have pointed out, the complexity of the calculations needed to understand the mathematical law governing a body in free fall is staggering.[37]

The complexity is true enough, and a serious problem for Descartes. However, there is another problem that Descartes had to face: a lack of appropriate experiments. In Part VI of the *Discours*, Descartes complains that to complete his system, he must do numerous expensive and time-consuming experiments. There is every reason to believe that this lack of experiments was one of the obstacles Descartes saw to the completion of a mathematical account of heavy bodies to rival that of Galileo. He wrote to Mersenne on 11 March 1640:

> I cannot determine the speed at which every heavy body descends at the beginning, since it is purely a factual question, and depends on the speed of the subtle matter.[38]

As Descartes notes elsewhere, in his letter to Mersenne on gravity from 13 July 1638, this is a question of fact 'that can be decisively answered by human beings only in so far as they are able to perform some experiment'.[39] But the speed of the subtle matter (and how it varies at different distances from the centre of the earth, perhaps) affects not only the speed at the first moment of fall, but the speed during every moment a body falls. (Indeed, it affects all aspects of the behaviour of bodies in the vortex, including the planets and comets.) Insofar as the speed of the subtle matter is 'purely a factual question', something that can only be learned through experience, so, then, the law of free fall would have to be based at least in part on experiment. Not the kinds of experiments that Galileo used to establish his law of free fall, of course. Galileo dropped balls, let them roll down inclined planes, watched as they swung at the end of ropes. But for Descartes, this is only the experience of bodies at the very beginning of their fall, and thus is not representative of the full course of their fall. On his conception of heaviness, what Descartes needs to establish the true laws of free fall empirically is the fall of bodies through much greater distances, distances sufficient for the true laws to reveal themselves to the observer, as bodies finally attain their maximal speed by virtue of being hit by the particles of subtle matter in the vortex. Such observations were simply not possible for Descartes to obtain. As he wrote to Mersenne in his letter of 13 July 1638, 'from experiments in our own atmosphere we cannot even tell what goes on much lower towards the centre of the earth or much higher, beyond the clouds . . .'.[40] What blocks a genuinely Cartesian mathematical physics of heavy bodies, then, is no conceptual problem, no problem with his ability as a mathematician or his ability to apply mathematics to physics. The difficulty is, it seems, an empirical difficulty, Descartes' inability to do the experiments or make the observations necessary to establish the true law of falling bodies.

Despite Descartes' effort to replace it with another conception of mathematical physics, the Galilean paradigm will remain influential in physics for almost half a century after Descartes' death. It will stand until the work of Isaac Newton, who figured out how to use observations of the moon and planetary motions to build a mathematical theory of heavy bodies that corrects Galileo's laws, something Descartes tried to do without success.

Notes

1 *Principia* II, art. 64.
2 AT iii. 39.
3 Alexandre Koyré, *Études Galiléennes* (Paris, 1939), ii. 46.
4 AT x. 52.
5 On this, and more generally on the place of mathematics in early modern Aristotelian thought, see Peter Dear, *Discipline and Experience: the Mathematical Way in the Scientific Revolution* (Chicago, 1995), ch. 6.
6 This seems to be the sense in which Isaac Barrow used the term; see Dear, op. cit., 178–9, 223–4.
7 See Dear, op. cit., 173.
8 From Galileo Galilei, *Dialogo . . . sopra i due massimi sistemi del mondo* (Florence, 1632), 189.
9 I mean to use the term 'paradigm' in the sense that Thomas Kuhn put it forward in his *Structure of Scientific Revolutions* (Chicago, 1962): paradigms are 'accepted examples of actual scientific practice – examples which include law, theory, application, and instrumentation together – [that] provide models from which spring particular coherent traditions of scientific research' (10). While the notion of a paradigm has many problems and complexities, and while Kuhn's general schema for the history of science is generally considered problematic, I think that the idea of a Galilean paradigm is quite illuminating in this particular and limited historical context.
10 On the sources of Galileo's thought, sources that also shape the thought of his mechanist contemporaries, see especially William A. Wallace, *Prelude to Galileo* (Dordrecht, 1981) and *Galileo and his Sources* (Princeton, 1984).
11 See Robert Lenoble, *Mersenne, ou la naissance du mécanisme* (Paris: Vrin, 1971), 39, 357–60, 391ff.
12 My comments in this paragraph are based on an examination of the copy preserved in the Bibliothèque des Arts et Métiers. Other copies vary somewhat as to contents and arrangement. This copy contains manuscript notes in Mersenne's own hand, and thus would seem to be authoritative.
13 Mersenne had touched upon it in bk. III, prop. 19 (20) of the *Harmonie Universelle*, and it is discussed in more detail in later sections of the book. The propositions in bk. III (*Du mouvement, de la tension, de la force, de la pesanteur, & des autres proprietez des chordes Harmoniques, & des autres corps*) are misnumbered, starting with prop. 6, incorrectly given as prop. 5, on p. 169. In the copy preserved in the Bibliothèque des Arts et Métiers, Mersenne himself corrected the errors in pen. (This copy is reprinted in facsimile, Paris, 1963.) The proposition in question is printed as prop. 19, but in reality is the twentieth proposition in the book. For discussions later in the book, see prop. 18 of '*De l'utilité de Harmonie*', at the end of the last book of the *Harmonie Universelle*, and the *Nouvelles observations physiques et mathematiques*, pp. 16ff, apparently added to the end of the book while it was in proofs.
14 Just as Mersenne was about to publish his *Harmonie Universelle* in 1636, there appeared a short work, *Geostatice, seu de vario pondere gravium secundum varia a terrae (centro) intervalla, Dissertatio mathematica*, by Jean de Beaugrand in which he discussed the question as to whether or not things have different weights in proportion to how far they are from the centre of the earth. The book

appeared too late for Mersenne to take account of it in his discussion of the question in bk. III. Even before it was published, Mersenne asked Fermat, a protégé of Beaugrand, for his opinion on the question, and included Fermat's answer in the discussion of the question in the later sections of the *Harmonie Universelle*. On this, see Michael Sean Mahoney, *The Mathematical Career of Pierre de Fermat, 1601–1665* (Princeton, 1973), 371ff. For further discussion of Mersenne, Fermat, and Descartes in connection with Beaugrand, see Pierre Costabel, 'Les enseignements d'une notion controversée: Le centre de gravité', in *Actes du Symposium International des sciences physiques et mathématiques dans la première moitié du XVIIe siècle* (Paris, 1960), 116–25; and Pierre Costabel, 'Centre de gravité et équivalence dynamique', in his *Démarches originales de Descartes savant* (Paris, 1982), 100–7. (I am grateful to Alan Gabbey for these references.) It is probable that Mersenne also asked Descartes for his views on Beaugrand's book at that time and, presumably, for comments on his own treatment of the question in the *Harmonie Universelle*. Cf. AT i. 390, where Descartes seems to be aware of Beaugrand's book in June 1637, though he had not yet seen it, and would not receive it for a year. When Descartes finally received the book in perhaps June 1638, he quickly responded to Mersenne's query and, in the letter of 29 June 1638, quickly dismissed Beaugrand's thoughts. (AT ii. 182–9.) (There are personal reasons behind his hostility to Beaugrand as well. For the story of their stormy relations, see Mahoney, op. cit., p. 50, and Gaukroger, *Descartes: An Intellectual Biography* (Oxford, 1995), 331.) The answer he gave Mersenne to the original query in the letter of 13 July 1638 may owe more to his reading of Mersenne's *Harmonie Universelle*. Descartes saw the *Harmonie Universelle* as early as the winter of 1637–8, on loan from Bannius; cf. AT ii. 150. The example of the flight of birds, found both in Mersenne, *Harmonie Universelle* bk. III prop. 19 (20), p. 207, and in Descartes, AT ii. 226, suggests that Descartes may have read at least the earlier discussion of the question in the *Harmonie Universelle*. There was also a continuing discussion of these questions between Fermat, Mersenne, Pascal *père*, and Roberval; see Mahoney, op. cit., pp. 376ff. It is not clear how much of that Descartes was aware of.

15 AT ii. 222ff.

16 AT ii. 226.

17 For a demonstration in physics to be 'mathematical' for Descartes seems to mean that it is made under certain ideal assumptions, which may be known to be false, but which make calculation easier. And thus, for example, in a letter to Mersenne on 28 Oct. 1640 he writes: '*. . . i'ai supposé, en ma Dioptrique, que la superficie & la bale sont parfaitement dures, & que la bale n'a ny pesanteur ny grosseur &c., pour rendre ma demonstration Mathematique*' (AT iii. 208).

18 AT ii. 227.

19 AT ii. 227.

20 Cf. the distinction Fermat draws between 'la pesanteur' and 'le poids'; see Costabel, 'Les enseignements', 117–18.

21 AT ii. 232ff.

22 AT ii. 232.

23 AT ii. 233.

24 AT ii. 239.

25 AT ii. 242ff.

26 Alan Gabbey has objected that this discussion in Descartes, as well as Beaugrand's *Geostatice*, actually fits into the tradition of Guido Ubaldo and Benedetti, a very different tradition from that of Galileo. In the strict sense, this may well be true. See especially Guido Ubaldo del Monte, *Mechanicorum liber* (Pesaro, 1577), in Stillman Drake and I.E. Drabkin, eds. and trans.,

Mechanics in Sixteenth-Century Italy (Madison, 1969), 265, 268ff, 271ff. See also Giovanni Battista Benedetti, *Diversarum speculationum mathematicarum et physicarum liber* (Turin, 1585), in Drake and Drabkin, *Mechanics*, 170, 176–7. In a letter to Huygens, 8 September 1637, AT i. 396–7, Descartes acknowledges that he has read Guido Ubaldo, as well as Mersenne's *Les méchaniques de Galilée*. Galileo, though, rejected these considerations in favor of a more orthodox Archimedean position, in accordance with which the true verticals of different bodies can be regarded as parallel. See Wallace, *Galileo and His Sources*, 241, 250, 252, 254, 340–1. But it is not at all clear that Descartes was entirely aware of Galileo's position on this. Furthermore, Galileo often takes into account the fact that the mechanical experiments he discusses are taking place on the surface of a sphere, and that it is an idealisation to assume that the true verticals are always parallel. It is, indeed, this observation that leads Galileo to say that bodies in motion tend to stay in motion in a circular path around the centre to which they tend; see, e.g., the version of that argument in Day I of Galileo's *Dialogo* (1632), in *Opere di Galileo Galilei* ed. A. Favaro (Florence, 1890–1909), vii. 53. As Mahoney (op. cit., 372–3) notes, the geostatic point of view was often assumed in many of the writings on mechanics from which Galileo and later authors draw, from Archimedes and the pseudo-Aristotle of the *Mechanica* on down. In this sense, the geostatic point of view, and the questions that it leads one to consider, feed directly into what I have called the Galilean paradigm. There is every reason to think that Mersenne and his friends saw Beaugrand's concerns as an integral part of this larger and broadly Galilean approach to mathematical physics, and did not sharply distinguish them from the Galilean tradition.

27 Cf. AT x. 582–99, where Adam and Tannery give a detailed account of the relation between the Descartes-Mersenne correspondence and the contents of the *Cogitata*. The relation between the letter of 13 July 1638 and Mersenne's publication is given at 595–6. Note, however, that on those pages what is printed as 't. III' (i.e. AT iii) should be given as 't. II' (i.e. AT ii).

28 AT ii. 271–2; iii. 613.

29 AT iii. 37–8; cf. AT i. 221–2, 228, 231, 261, 304–5, 392; ii. 355, 385, 386, 630; iii. 9, 11, 164–5; iv. 687–8, 707–8.

30 AT ii. 387.

31 AT ii. 227.

32 Mersenne himself seems to have become convinced by Descartes' position in the years following the publication of the *Cogitata*. On this, see Peter Dear, *Mersenne and the Learning of the Schools* (Cornell, 1988), 210–19.

33 Koyré, op. cit., i. 74.

34 AT i. 231.

35 AT xi. 629–31. I suspect that this was preserved mainly for the comments Descartes makes there about the way that mind could move bodies, and not for the comments on free fall; one wonders about how many other attempts to deal with this problem there were in Descartes' notebooks that Leibniz simply passed over, and that are now irretrievably lost.

36 Paul Tannery, in Descartes, *Correspondance,* ed. C. Adam and G. Milhaud (8 vols., Paris, 1936–63), iii 83n; quoted Emily Grosholz, *Cartesian Method and the Problem of Reduction* (Oxford, 1991), 99. See also Grosholz, op. cit., ch. 5; Stephen Gaukroger, 'Descartes' project for a mathematical physics', in Gaukroger, ed., *Descartes: Philosophy, Mathematics, and Physics* (Sussex, 1980); Koyré, op. cit., ii. 45ff.

37 For a similar explanation for why Descartes did not publish a mechanics, see Alan Gabbey, 'Descartes' physics and Descartes' mechanics: Chicken and egg?', in Stephen Voss, ed., *Essays in the Philosophy and Science of René Descartes* (Oxford,

1993), 311–23. A second problem for a mathematical physics might seem to come from Descartes' *Géométrie*, and the exclusion of transcendental curves from mathematics proper. One might suppose that by limiting himself to algebraic curves, Descartes denies himself the tools he needs to represent the actual motion of bodies. Cf. J. Vuillemin, *Mathématiques et métaphysique chez Descartes* (Paris, 1960), 97. I am not sure that this would have been a real problem for Descartes. In the discussion of the heaviness problem, Descartes seems quite willing to talk about spirals and their properties in connection with motion. In general, in his correspondence, he is willing to talk about the properties of certain curves (the roulette or cycloid, for example) which do not fall within his geometry. Also, in the correspondence, he seems to be willing to use infinitesimal methods of the sort that he seems to avoid in the *Géométrie* proper. There are two possible explanations. One might be that even though they are outside of geometry proper, they are still interesting and worth talking about for Descartes. Or, alternatively, in the correspondence, we may see him in the process of changing his mind about the domain of mathematics. But this is another essay for another day.

38 AT iii. 36.

39 AT ii. 224.

40 AT ii. 224–5.

6 Causal powers and occasionalism from Descartes to Malebranche

Desmond Clarke

All natural causes are . . . only *occasional* causes.

Malebranche, *De la recherche de la verité*

During the period between the death of Descartes in 1650 and the publication of Nicolas Malebranche's *De la recherche de la verité* (1st edn. 1674/5), most Cartesians turned in the direction of occasionalism in discussions of causality. However, despite the widespread approval for the new language of occasionalism, it is neither clear nor generally agreed what was meant by 'occasional causality', and any progress in its clarification presupposes an examination of the reasons, or at least of some of the reasons, why Cartesians introduced this apparently novel idea.[1] Louis de La Forge (1632–64) was among the first exponents of Descartes' theories to write systematically about occasional causality, and for that reason I shall focus in some detail on his analysis of the topic. I shall then examine the extent to which La Forge's analysis can be used to clarify the initially ambiguous signs in Descartes' theory of causality and, somewhat briefly, the extent to which it sheds light on the mature version of the theory which was later expounded by Malebranche. The focus of this discussion is the identification of the philosophical or theological question(s) for which occasionalism was proposed by Cartesians as a solution.

One of the developments which initially brought the issue into focus was the elimination of various so-called 'occult powers' from the explanatory repertoire of Cartesian natural philosophy. Descartes argued against scholastic forms and qualities because (a) they are redundant as explanations;[2] (b) they are not clearly understood;[3] (c) they compromise the distinction between matter and mind;[4] and (d) the mechanism by which they allegedly operate is obscure.[5] This implies that if the mechanical forces to which Cartesians appeal in order to explain why bodies move were understood as scholastic forms and qualities, the elimination of the latter would also imply the elimination of all active principles from Cartesian nature. And since God is already involved in every instance of causal agency, the simplest causal theory would be that God acts directly on natural phenomena without the mediation of any genuine finite causes.[6] That is one interpretation of occasionalism. However, whether Cartesian forces are eliminated so cleanly as non-entities remains to be seen.

A second factor in the development of occasionalism was the parsimony of the metaphysical categories that Descartes introduced, especially in the *Principia*, as a replacement for the metaphysics of the schools. Using Occam's razor with determination and dexterity, Descartes reduced the number of metaphysical categories that are available to accommodate our descriptions of any reality to two. These were: substance and the modes of a substance.[7] Modes are such that they cannot exist apart from the substance of which they are modes. This was understood in the strict sense that each mode is, by definition, the mode of a specific substance – such as the shape of a particular physical thing – and it cannot be transferred from one substance to another. Evidently the modes of any substance may change; for example, the shape or speed of a moving body may change, and in that case it acquires new modes. But the shape of one body cannot be transferred to another, even if it loses its shape and if, in a simultaneous modal change, a second body acquires exactly the same shape.

Not only are modes necessarily confined to the substance of which they are modes, but there is a general distinction between two kinds of substance, namely spiritual and physical substances, and there is a corresponding distinction in Descartes' ontology between the two kinds of modes that those substances are capable of supporting. Physical substances are capable of having only physical modes, and spiritual substances are capable of having only spiritual modes. Thus a soul cannot have a shape, and a body cannot think. This restrictive and dualistic ontology implies that, no matter what kinds of reality are required in the construction of Cartesian physics or in the causal explanation of any events, mental or physical, they must be either modes or substances and, if they are modes, they must be modes of the appropriate type of substance.

Finally, Descartes assumed a version of the traditional scholastic account of God's agency in relation to created reality, in this sense: God is the universal, general, or transcendent cause of everything that happens in the universe, and God's causality makes possible whatever kind of causality is available to creatures. The problem of conceptualising and reconciling the two kinds of agency involved here became acute in the late sixteenth century when philosophically sophisticated theologians disputed the sense in which human beings could be causes of their own free actions, and could therefore be held morally responsible for them, while God is also the general cause of free human actions without being responsible for moral evil. Descartes is somewhat agnostic about whether our limited minds can explain how these two claims are compatible.[8] When he raises the question in the *Principia Philosophiae* about how God's pre-ordination of everything is compatible with human freedom, he concedes that he has no theory with which to reconcile them; but he also argues that 'it would be absurd just because we do not comprehend one thing which, of its very nature, we know should be incomprehensible to us, to doubt something else of which we have a profound understanding and that we experience in ourselves'.[9] The result is that we are left with parallel accounts of God's agency and of human agency, without a satisfactory theory of how they are compatible or how they interact.[10] Descartes also adopted the Thomist thesis to the effect that there is no real distinction between God and divine agency; thus God's agency is eternal, although many of the effects of that agency are manifest in time.[11] From the point of view of our continued existence and the limited causal agency that we enjoy, God's agency is understood as some kind of transcendent, eternal act in the background which is a condition for the possibility of human agency.

With these background assumptions, Descartes identified matter and its motion as the central explanatory concepts of his natural philosophy. Although causality is evidently not limited to changes in the motion of bodies – because, in the Cartesian world, the existence of all finite realities, including ideas, requires a cause – many nuances of occasionalism emerge in the context of explaining what makes pieces of matter move. Descartes distinguishes between motion as commonly understood and motion strictly understood, and the latter is defined as 'the transference of one part of matter or of one body from the vicinity of those bodies that immediately touch it and are regarded as being at rest, to the vicinity of others'.[12] This provides Descartes with a non-relativistic concept of motion without recourse to an absolute reference frame. The motion of a particular body is defined not by reference to some framework which is considered to be at rest, but by reference to the other bodies in its immediate vicinity. Thus a man walking on the deck of a ship is in motion relative to the deck, but whether he is also in motion relative to the shore or to the stars is irrelevant to questions about what makes him move on the deck of the ship.

Descartes then distinguishes between motion understood in this sense, which is a mode of the body in motion, and the force or action which causes the motion:

> And I say 'the transfer' as opposed to the force [*vis*] or action [*actio*] which brings about the transfer, to show that motion is always in the moving body as opposed to the body which brings about the movement. . . . I want to make it clear that the motion of something that moves, like the lack of motion in a thing that is at rest, is a mere mode of that thing and not itself a subsistent thing, just as shape is a mere mode of a thing that has shape.[13]

Thus motion in the sense of transference is understood as an effect of some cause, and the cause in question includes the force or action which makes something move.

One way of interpreting Descartes' theory is to say that, despite the alleged role of forces in this analysis, there are no real forces in nature and that the transference which seems to be caused by various forces is actually caused by God directly.[14] This interpretation suggests that bodies do not genuinely move other bodies, even if they appear to do so and, in general, that bodies do not causally affect the mind and vice versa. However, before deciding on the elimination of forces from the natural world of the Cartesians, it is worth considering the detailed analysis of bodies as causes which was developed by Louis de la Forge in his efforts to interpret faithfully Descartes' theory of mind.

Louis de La Forge

In his *Traité de l'Esprit de l'Homme* (1666),[15] La Forge takes up the analysis of causality at the point where Descartes left it. On first reading it seems as if everything about La Forge's exposition of mind-body interaction and of the way in which one body affects another implies that created things do have causal powers. In the case of bodies, the causal forces are described as dispositional properties, in virtue of which bodies in motion tend to continue in motion and bodies at rest tend to continue at rest. Here are a few examples: 'God . . . gave to each thing the power [*force*] to maintain itself in whatever state it is until it is moved from that state by something else'[16]; 'for by not distinguishing the power [*force*] which the body has to move itself from the power by which some movements of the body are subject to the will of the mind, some people have thought that the mind is a body'[17]; 'the force [*force*] which all things have to maintain themselves in whatever condition they are in . . .'.[18] La Forge speaks equally plainly about the way in which the mind affects the body and the body affects the mind:

> I think it is so obvious that the decision of our will makes us move some of our limbs which would not otherwise move that it is not necessary for me to distract myself in proving it, for there is no one who is not taught this by their own experience.[19]
>
> No one doubts that the mind and body are . . . both capable of acting and being acted on. For a body is acted on when it is moved, and it acts when it pushes another body. . . . the actions of the body would cause the mind to be acted on and the actions of the mind would cause the body to be acted on.[20]
>
> We must move on and see how the human mind and body have the power to act on one another.[21]

La Forge also urges that these causal powers cannot be understood as scholastic occult powers, such as sympathy and antipathy; the latter are meaningless terms that do not correspond to any clear idea.[22] Not surprisingly, he dismisses scholastic forms and qualities for some of the same reasons as Descartes. One reason given is that they are mere qualities which behave as if they were substances;[23] second, such occult powers compromise the distinction between mind and body.[24] But the most interesting and apparently uncartesian reason is that, whatever the nature of these powers may be, if they are genuine powers *in bodies*, we must be capable of imagining them. If we cannot imagine them, they are beyond the scope of our knowledge.

> . . . We do not understand anything about bodies and we can know nothing about them apart from what can fall within the scope of our imagination and of which that faculty can provide us with a clear and evident idea. It follows that all those who introduce causes which their imagination cannot conceive, as the proximate principles of bodies and of the changes which occur in them, are blind people who wish to lead others who are blind. For even if we knew by revelation that these were the real principles of nature, their obscurity would still make them completely useless. I do not think that anyone could deny that, among all the ideas of the imagination, the only ones that we conceive distinctly are those of extension, size, shape, motion and rest, position and the relation of parts. . . . We know nothing in physical nature apart from things to which these primary ideas apply, and therefore we do not conceive at all of anything else that we assume in bodies – such as, for example, the quality which the schools call weight or what they call an impressed quality, which has the force to move bodies – because we could not imagine what it is and, in respect of bodies, we understand only what our imagination is capable of conceiving.[25]

It may be that the powers in question are purely mental and could therefore be conceived by the mind alone without any assistance from the imagination. But if they are understood as powers in bodies, they must be imaginable and must fall within the range of the ideas listed by La Forge, including those of motion and rest.

We may conclude that, if any powers are predicated of minds or bodies, they must be either substances or modes of substances and, since causal powers could hardly be substances in their own right, it follows that they are modes. Second, if they are predicated of bodies, they must be bodily modes which are conceivable within the range of concepts with which we represent bodies and their modes in our imagination.

Why not simply say, then, that bodies and minds have causal powers and that in each case they are modes of the corresponding substance? To answer this question, one needs to look more closely at one of La Forge's arguments in support of the occasionalist thesis, which is most comprehensively expounded in Chapter 16 of the *Traité*, entitled: 'How the Mind and Body Act on each other, and how one Body moves another'.

> To discover, if we can, the cause of all the motions that we observe in bodies, we should distinguish between a movement and its determination and between the cause of a movement and the cause which determines it, because one is often different from the other just as movement is from the force which makes something move. For motion, considered in the body which is moved, is simply [here La Forge quotes Descartes' definition of motion in the strict sense given above (p. 133)]. Thus motion is only a mode which is not distinct from the body to which it belongs and which can no more pass from one subject to another than the other modes of matter, nor can it belong to a spiritual substance.[26]

What is at issue here is what Descartes and La Forge call motion in the strict sense, and not the force which causes motion. Since motion as transfer is a relationship between one body and other bodies in its vicinity, it can be predicated only of something which is itself a body, and this relationship evidently cannot move from one body to another. La Forge then continues:

> But the motive force, i.e. the force which transports a body from one vicinity to another and which applies it successively to different parts of the bodies which it leaves behind, which is also sometimes called 'motion', is not only distinct from this application but also from the body which it applies and moves. . . . Now if the force which moves is distinct from the thing which is moved and if bodies alone can be moved, it follows clearly that no body can have the power of self-movement in itself [*de lui-même*]. For if that were the case this force would not be distinct from the body, because no attribute or property is distinct from the thing to which it belongs. If a body cannot move itself, it is obvious in my opinion that it cannot move another body. Therefore every body which is in motion must be pushed by something which is not itself a body and which is completely distinct from it.[27]

La Forge argues from the clear and distinct ideas of matter and mind that the power to move a body is not conceptually linked with the idea of extension. We can think of a piece of matter that does not have this power, and we can think of the power as present even in the human mind or God, neither of which is material.[28] Thus motive force is not a mode of bodies in the way that shape is; it is not a mode that bodies have in virtue of being extended. It follows that motive force must belong as a proper mode to spiritual substances. This suggests a distinction between modes which are essential to a substance or which are linked conceptually with the defining attribute of a substance, and modes which may be otherwise present in them.

There is nothing unusual in the suggestion that the power to move bodies is not essential to bodies; La Forge claims that the power to move a body is not essential to the human mind either. In each case the argument relies on the allegedly clear and distinct idea of mind or body. In the case of the mind, the question comes into focus when describing the powers of separated souls after death:

> Far from pretending that we could know what would be the magnitude and extent of the power we would have [after death] to move bodies, we do not even know if we would have any power at all over them . . . because none of these things belongs to the essence of the mind and its will has no power outside itself except to the extent that it pleased God to give it such power.[29]

In other words, the power to move bodies is not essential to minds and, if they have this power, they have it only because it was superadded to minds as a supplementary power by a decision on God's part; in contrast, the power of thinking and willing are essential powers of the mind.[30]

The conclusion of this argument is, not that bodies do not have the power to move other bodies – because even souls do not have this power as an essential attribute – but that bodies do not have such a power *from within themselves*. Neither minds nor bodies have the power to move bodies as an essential or proper attribute; if they happen to have this power, it must be because it was given them by God, who regulates the way in which these powers operate by the laws of nature (in the case of bodies) and by the laws of interaction for mind and body (which, equally freely, he prescribed). However, if bodies could be given an acquired power of this kind, it would have to be classified as a mode rather than a substance, although in God it could not be a mode because God is not subject to change. That is exactly what La Forge says, when describing the force that moves parts of matter: 'Indeed, this force in a created substance is really a mode of substance, but it is not so in God'.[31]

This coincides with the description of another power in bodies, the power to remain in whatever condition they are in. God has such a power in himself necessarily, and in the case of God it is not distinct from his essence.

> This power in God is nothing but the very immensity of his essence. However, when he [Descartes] speaks in the *Principia* about the force which all things have to maintain themselves in whatever condition they are in, he thinks about this force as dependent on the command of God who has himself established the laws of nature in the immutability on which they are founded and not on any power which may be in them independently [*aucun pouvoir qui soit en elles sans dépendance*].[32]

Thus bodies are moved by other bodies or by minds; this happens in virtue of powers that minds or bodies really have, but which do not belong to them essentially. In each case, the powers are acquired from God and are the relevant modes in virtue of which bodies or minds can move bodies.

Of course, La Forge also argues that since God 'is the first of all beings on whom all things depend both in their essence and their existence, as their principal and in some sense their total cause who causes them to exist and to be what they are',[33] God is ultimately responsible for every condition, of motion or rest, of every body. It is important to recognise that God's universal causality applies equally to motion and to rest.

> We are convinced by the immutability of this decree that he will never annihilate the things which he has once created, and it is through knowledge of this immutability that Mr Descartes proposed in the *Principia* that God conserves by the same action the same quantity of motion and of matter which he created at the beginning. It is from this unity of action and this immutability that originates the force which each thing has to maintain itself in whatever condition it is, namely, those that move to remain in motion and those at rest to remain at rest, separated things to remain in their separation and united things in their union, until they are pushed by something with a stronger force from that condition.[34]

This raises problems about the role of God's causality in relation to the apparent causality of created things; one may wonder whether finite causes are genuine causes at all or, if God is so causally active, whether finite causes are redundant?

La Forge repeats the caution quoted earlier from Descartes, that 'our understanding is very limited and the greatness of God is infinite',[35] and he quotes in support the text from the *Principia* (I, art. 41), where Descartes tried to reconcile human freedom with God's comprehensive causality:

> We shall have no trouble in avoiding this difficulty if we remember that our thought is finite and that the knowledge and omnipotence of God is infinite. . . . It would be a mistake to doubt something which we perceive inwardly and which we know from our experience is in us, because we do not comprehend something else which we know is by its nature incomprehensible.[36]

A similar kind of compatibilism between divine and human agency is extended to bodies. 'Although God is thus the universal cause of all the motions which occur in the world, I also recognise bodies and minds as the particular causes of these same motions.'[37] And even more explicitly in the same chapter:

> However you should not say that it is God who does everything and that the mind and body do not really act on each other. For if the body had not had such a movement, the mind would never have had such a thought, and if the mind had not had such a thought the body might also never have had such a movement.[38]

Even when La Forge distinguishes, in the language of Suárez, between univocal and equivocal causes – where univocal causes are those where 'the effect resembles the cause, and others are equivocal where the effect does not resemble the cause'[39] – and then classifies the mind as an equivocal cause of what happens in the body, and the body as an equivocal cause of what happens in the mind, he cautions the reader:

> However it does not follow that the body is not the cause of the thoughts which arise in the mind on its occasion, nor that the latter is not equally the cause of the movements which occur in the body as a result of its thoughts, just because they are only equivocal causes. For God is no less the Creator of all things, and workmen are no less the authors of their workmanship, despite the fact that they are all merely the equivocal causes of these effects.[40]

For this reason, there is no more difficulty, and no less, in understanding 'how the human mind, without being extended, can move the body and how the body without being a spiritual thing can act on the mind, than to conceive how a body has the power to move itself and to communicate its motion to another body'.[41] It is taken for granted that, by divine decree, the mind and body do interact causally with each other, and the only situation in which this becomes problematic is when the soul is separated from the body; then it is no longer clear what power it may have to move bodies or to be affected causally by them, for example in sensation.[42]

The references to God in this account of the agency of finite causes may be understood minimally as an effort to reflect what most scholastic philosophers believed, viz. that the existence of everything in the universe depends on God's agency in creation, and therefore that God stands in relation to finite created realities as some kind of ultimate, general or primary cause. Second, insofar as we can speak meaningfully in human language about God's agency, God is immutable and whatever is done atemporally by him does not change over time as we observe the initiation and completion of actions on earth.

> We also know that God is a very perfect being and therefore his will is immutable. If it seems to us that changes in nature indicate some change in God and even if he sometimes speaks to us in Scripture as if he regretted something and changed his mind, that is because he accommodates himself to the weakness of our understanding, which is

> too limited to conceive . . . the way in which he changes the whole of nature without changing himself.[43]

The agency of created being depends in some sense on God. But we can neither understand nor describe adequately what that sense is. What we are offered by La Forge are various metaphors which could not possibly describe how God's agency interacts with ours and were never meant to do so.

All this leaves open the possibility that there is genuine agency in the world around us. The central feature of La Forge's analysis is his answer to the question: what makes a body move? If the answer is: 'force', that raises a question about what kind of reality a force is and how it can be described within the categories available in Cartesian metaphysics. La Forge is clear enough about what force is not. It cannot be one of those occult powers which he claimed the scholastics exploited to develop pseudo-explanations; nor can it be a substantial form or real property, because then it would really be a substance that masquerades as a property. Thus finite powers may be either modes or nothing at all. However, it is unlikely that powers are nothing at all. For whatever story is told about created things and their causal powers, La Forge must be able to speak coherently about God's power; and in the case of God this cannot be a nothing, because in that case the whole explanatory account would come to nothing. So, at least in the case of God we need a concept of genuine power and, on La Forge's analysis of our God language, we can acquire this concept only by first looking at the world around us and forming the concept of power as it applies to created causes. The concept of power in God is subsequently constructed by analogy with the concept of a causal power in created substances. Thus it seems as if causal powers in finite substances are genuine, even if only modal, realities.

But if La Forge admits causal powers as modes of created substances, why introduce the language of occasionalism at all? His answer was:

> It does not seem to me that what theologians say, when they claim that a creature could not be the proximate principle of its action, is contrary to what we have just said, viz. that the mind and the faculty of thinking are identical. . . . I think they wish to say simply that there is no creature which can act without the simultaneous assistance of the Creator. That is very true.[44]

The conclusion suggested by these texts is that occasionalism is a way of talking about finite causes which adequately recognises both the reality of finite causal powers and their inexplicable and ineffable dependence on God's infinite causality. Occasional causes are neither unreal nor inefficacious; nor are they independent. 'Occasional' in this context means dependent on God.

Descartes

This interpretation by La Forge identifies some of the occasionalist connotations in Descartes' theory of causality. For despite his consistent objections to occult powers and faculties, Descartes had no objection to using the concept of a faculty or power as an acceptable explanatory category in selected contexts. Thus, in the *Meditationes*, we are said to have a passive capacity for being affected in sensation and this passive capacity on our part must be matched, he argues, by a corresponding active power in the bodies which cause our sensations.[45] Since God has given me no faculty for recognising any source of ideas apart from external objects, 'I do not see how God could be understood to be anything but a deceiver if the ideas were transmitted from a source other than corporeal things'.[46] Thus external physical objects and events have active powers to cause our sensations. The human mind also has definite, distinct powers of thinking and willing, and we furthermore experience in ourselves the power to move our bodies.[47] These references to powers prompted Hobbes to object that Descartes seemed to be 'going back to the scholastic way of talking: the understanding understands, the sight sees, the will wills'.[48]

Apart from appealing to powers, faculties and forces, in select explanatory contexts, Descartes is consistent in claiming that mind and body do interact causally. For example, he wrote to Arnauld in 1648:

> That the mind, which is incorporeal, can set the body in motion is something which is shown to us not by any reasoning or comparison with other matters, but by the surest and plainest everyday experience. It is one of those self-evident things which we only make obscure when we try to explain them in terms of other things.[49]

The interaction of mind and body in both directions is acknowledged in one of Descartes' famous letters to Elizabeth, using the term 'power' [*force*] to describe the capacity of each substance to affect the other causally:

> Lastly, as regards the soul and body together, we have only the notion of their union, on which depends our notion of the soul's power to move the body, and the body's power to act on the soul and cause its sensations and passions.[50]

This suggests that one would need a particularly strong argument for claiming that Descartes does not accept powers or forces, or that he rejects genuine causal agency between mind and body in both directions.

One reason offered for this thesis is that there is no appropriate metaphysical category which could accommodate such powers, because they would have to be either substances or modes. However, Descartes acknowledges the limited categories available and classifies 'active principles' as modes. In the letter to Regius in which he tries to avoid a dispute with Voetius, he urges:

> It would be absurd to say this [viz. that substantial forms are the immediate principles of action] if one does not regard such forms as distinct from active principles. Now we do not deny active principles, but we say only that they should not be regarded as having any degree of reality greater than that of modes . . . nor do we deny dispositions, but we divide them into two kinds. Some are purely material . . . others are immaterial.[51]

There are irenic motives apparent elsewhere in this lengthy letter and one might argue that Descartes was stretching his philosophy to avoid controversy with Regius' theological critics. But even the *Principia* includes a number of key texts which acknowledge the role of forces in moving bodies or in maintaining them at rest. For example, in describing the scope of the Third Law of Nature:

> All the particular causes of the changes which bodies undergo are covered by this third law – or at least the law covers all changes which are themselves corporeal. I am not here inquiring into the existence or nature of any power [*vim*] to move bodies which may be possessed by human minds or the minds of Angels.[52]

The exclusion of the powers of minds or angels suggests that Descartes is inquiring into the existence or nature of the powers which bodies have to move other bodies. Having argued for the Third Law in articles 41 and 42, he begins article 43 as follows:

> *The nature of the power which all bodies have to act on, or resist, other bodies.*
>
> What is it that constitutes the power [*vis*] of any given body to act on, or resist the action of, another body? It consists simply in the fact that everything tends, so far as it can, to persist in the same state, as laid down in our first law. Thus what is joined to another thing has some power [*vis*] of resisting separation from it; and what is separated has some power of remaining separated.[53]

Descartes suggests that the mechanical powers involved here are easy to understand and that, in contrast, we cannot make any sense of the real qualities or substantial forms of the scholastics.

> We understand very well how the different size, shape and motion of the particles of one body can cause [*excitentur*] various local motions

> in another body. But there is no way of understanding how these same attributes [viz. size, shape and motion] can produce [*producatur*] something else whose nature is quite different from their own . . . we cannot understand how these qualities or forms could have the power [*vim habeant excitandi*] subsequently to cause local motions in other bodies.[54]

The same particles of matter in motion can cause sensations in us:

> We know that the nature of our soul is such that different local motions are sufficient to cause all the sensations in the soul. . . . In view of all this we have every reason to conclude that the properties in external objects to which we apply the terms 'light', 'colour', . . . are . . . simply various dispositions [*dispositiones*] in those objects which make them able to set up various kinds of motions in our nerves.[55]

That sums up Descartes' analysis of causal powers in bodies. They are not spirit-like substantial or real qualities in the scholastic sense, but are dispositions of bodies at rest to remain at rest and of bodies in motion to remain in motion. Such dispositions are not really distinct from the substances to which they belong because, according to Descartes' ontology, they are modes, and modes are by definition not really distinct from the substances to which they belong. Thus the powers of bodies are modal dispositions.

Malebranche and Cordemoy

The same conclusion emerges from the analysis of causality which is proposed in Gerauld de Cordemoy's *Le Discernement du corps* (1666).[56] Cordemoy is primarily concerned with physical causes and the explanation of motion, and he develops his analysis in the form of definitions and axioms, from which the occasionalist conclusion follows. Although he distances himself from Descartes' definition of matter, he endorses the relevant feature in that definition which is crucial for occasionalism, viz. that motion or the ability to cause motion is not an essential property of matter. It follows that, however we explain motion and whatever we identify as its cause, it must be the case that the ultimate or primary cause of motion is a reality about which it makes sense to say that motion, or motive force, is one of its essential properties.[57] This cause must be spiritual and, given the dependence of finite causes on God, it must ultimately be God.

Malebranche's wide-ranging development of the occasionalist thesis can hardly be summarised in a few paragraphs. Besides the arguments that were borrowed and adapted from Descartes and La Forge, Malebranche introduced an apparently novel definition of a true cause in *De la recherche de la verité*: 'A true cause as I understand it is one such that the mind perceives a necessary connection between it and its effect'.[58] The qualification 'necessary' implies a contrast with causes which are contingent on the activity of other causes and are therefore such that they cannot exercise their causality without the co-operation of some other cause. This is equivalent to another definition of a true cause offered by Malebranche: 'By a true cause I understand a cause which acts by its own force'.[59] This in turn raises the question whether the force by which any putative cause acts is something which is essential to it or something which is, in some sense, provided by a different cause. Given the assumed universal dependence of all causes on God, it is a short step to the conclusion that 'no creature can act on any other creature through its own [*qui lui soit propre*] efficacy . . . everything depends on God because all causes can act only through the efficacy of the divine power'.[60] There is no objection here to the claim that finite causes have causal powers; the objection is to those 'who maintain that creatures have force and power *in themselves* to act in that way'.[61]

Of course Malebranche also considers many other arguments in support of occasionalism. These include developments of familiar Cartesian objections: motive force is not a mode which can belong to a body as such; even if bodies had a motive force, it could not pass from one body to another because, by definition, no modes can transfer from one substance to another; God acts by the simplest means possible and therefore, in our theory of the causal agency of finite causes, it is redundant to postulate the existence of any more powers or faculties than are strictly necessary to construct a viable explanation, given the fact that God is already active in the universe. But the fundamental intuition which motivates the introduction of the language of occasionalism is the recognition of the parasitic character of finite or created causes which can exercise their causal efficacy, however it is described, only dependently on God's causality.

God's causality

If Cartesians were so anxious to acknowledge the transcendent power of God and to demote finite causes to an appropriately dependent role, it raises a question about the availability of concepts with which to speak so confidently about the ineffable. How can we speak about a God who transcends human conceptions? The Cartesian answer, at least in discussing powers, is to follow the strategy suggested by Aquinas. We know what powers are in human experience and we extrapolate them, analogically, to God.[62] But that presupposes that the concept of a power must have a literal, original use in the case of human beings or in our experience of the natural world. Descartes accepts, as something which is beyond dispute, that our minds and bodies interact causally, although he cannot explain how this happens. He also accepts as equally beyond contention that bodies cause motion in other bodies by impact and that, in collisions, there is a power in a moving body to cause others with which it collides to move, and there is a power in bodies at rest to resist the imposition of motion from an external source. All these causal interactions rely ultimately on God; there is then a question about constructing a coherent account of how God can be the total cause of everything without making created causes redundant.

A brief reference to a similar problem in the case of existence may help. It is obvious that finite beings exist in some genuine sense of the term. Descartes thinks that existence is a quality which we do not get from ourselves but which comes exclusively from God, and that it requires God's constant concurrence to prevent us from lapsing back into nothingness.[63] The fact that our existence is owed completely to God does not imply that we do not genuinely exist, but simply that our existence is contingent or dependent. A similar relation obtains in the case of causal powers or forces. These are real features of created bodies and minds in virtue of which they interact causally. But such causal powers are not necessarily a feature of the bodies or minds in question; they are there only because God put them there.

One might even adapt to the discussion of occasional causality the kind of compatibilism suggested by Descartes for human freedom and God's total causality. If we begin our account with observed causal interactions and interpret these in the light of Cartesian metaphysics, we are led to God as their ultimate cause. God and his causal agency are described by analogy with created causes and their powers; but if anything goes awry in the construction of a coherent theory, or if there emerge apparently inconsistent elements in the total story, we should not overturn the very premisses from which we began. We should not reject the concept of a causal power which was derived from, and which applies principally rather than analogically to, finite causes.

What then is meant by 'occasionalism'? It is not primarily a theory of God's causal agency, nor is it a projection onto God of the discreteness and temporality of the actions by which finite agents are causally effective.[64] Occasionalism is a description of the causal agency of finite causes which recognises the extent to which they all depend ultimately on God, both for their existence and their causal efficacy. Second, it specifies a description of the causal powers of finite causes as modes of the substances involved, rather than as substance-like scholastic qualities. The modal status of causal powers and their ultimate dependence on God merge in the third feature to which occasionalism draws the attention of Cartesian philosophers. Mind and body are both defined by properties which are specific to their natures; a capacity to affect other bodies or minds causally is not such an essential property. Thus, whenever causal powers are found in finite causes, they are present there only because God decided to add them to the relevant substances and to control their operation by the laws of nature or the laws of the interaction of mind and body. In this sense, occasionalism is a consequence of Cartesian voluntarism.[65]

Notes

1 Recent discussions include: Thomas V. Morris, ed., *Divine and Human Actions* (Ithaca, 1988); Daniel Garber, *Descartes' Metaphysical Physics* (Chicago, 1992); Steven Nadler, *Causation in Early Modern Philosophy* (University Park, Penn., 1993). I agree with Nadler's thesis that occasionalism was not devised as a means of coping with the intractability of mind–body interaction; see S. Nadler, 'Occasonalism and the mind–body problem', in M.A. Stewart, ed., *Studies in Seventeenth-Century European Philosophy* (Oxford, 1997), 75–95.

2 *Le Monde* AT xi. 7–8; *Météors*, AT vi. 239; *Principles* AT vii-B. 238.

3 Descartes to Regius, January 1642, AT iii. 506–7; *Principes de la Philosophie*, AT ix-B. 319–20.

4 Descartes to de Launay, 22 July 1641, AT iii. 420.

5 *Principes*, AT ix-B. 322.

6 Garber argued that the scholastic world included various active principles in nature which mediated between God and natural phenomena. 'But in a physical world whose only constituents are extended bodies . . . what Descartes chooses in their place is God, who will act . . . as the direct cause of motion and change in the world.' *Descartes' Metaphysical Physics*, 274–5.

7 *Principia*, AT viii-A. 56; he also uses the language of attributes and qualities, but these are all ontologically equivalent to modes, considered from different perspectives.

8 Descartes to More, 5 February 1649; AT v. 272: 'I know that my intellect is finite and God's power is infinite, and so I set no limits to it; I consider only what I am capable of perceiving, and what not, and I take great pains that my judgement should accord with my perception. And so I boldly assert that God can do everything which I perceive to be possible, but I am not so bold as to assert the converse, namely that he cannot do what conflicts with my conception of things – I merely say that it involves a contradiction.'

9 *Principia*, AT viii-A. 20. Cf. Descartes to Elizabeth, 3 November 1645; AT vi. 332–3: 'Just as knowledge of God's existence should not prevent us from being certain of our own free will, because we experience it and feel it in ourselves, in the same way knowledge of our free will should not make us doubt the existence of God.'

10 This point is made by Elizabeth, on 30 November 1645; AT iv. 336: 'I also admit that, even though I do not understand how the independence of free will is no more incompatible with our idea of God than its dependence would be incompatible with its liberty, it is impossible for me to put the two of them together.'

11 Descartes to Elizabeth, 6 October, 1645; AT iv. 314.

12 *Principia*, AT viii-B. 53.

13 AT viii-B. 54.

14 Thus Garber – op. cit., 299 – writes: 'God is the only real cause in the world, at least in the world of bodies. On this view, the changes that a body can cause in a mind in producing a sensation or a mind can cause in a body in producing a voluntary action, are all due directly to God, moving bodies or sensations in minds on the occasion of other appropriate events.'

15 All references to La Forge are to the *Oeuvres philosophiques*, ed. P. Clair (Paris, 1974), and are identified as *Traité*. Translations are taken from *Treatise on the Human Mind*, trans. D.M. Clarke (Dordrecht, 1997); these are identified as *Treatise*.

16 *Traité*, 226/*Treatise*, 135.

17 *Traité*, 111/*Treatise*, 38.

18 *Traité*, 142/*Treatise*, 64.

19 *Traité*, 153/*Treatise*, 73.
20 *Traité*, 212–13/*Treatise*, 124.
21 *Traité*, 244/*Treatise*, 150. Cf. 'it [our will] has the power [*pouvoir*] to move our limbs directly by willing to move them.' *Traité*, 220/*Treatise*, 130.
22 In speaking of his own explanation of natural aversions and inclinations, La Forge contrasts them with the scholastic alternative. 'I also think that those who like to have recourse to sympathy and antipathy, which are obscure terms which mean nothing and which are only good for disguising our ignorance under the mask of some fancy words, according to the usual style of peripatetic philosophy, should not be preferred to us.' *Traité*, 313/*Treatise*, 204.
23 'They imagined this force as if it were a real quality or accident in the scholastic sense, which they think of as being completely distinct both from God who moves and from the bodies which are moved . . . that would be a substance which they call an accident and, indeed, a corporeal substance which could be divided and would have the power to move itself when moving others.' *Traité*, 242/*Treatise*, 148.
24 'For one thinks of them as united with matter either as one extended thing is united with another extended thing, or as something which is not extended with something which is so. If it is the former, it is similar to the union of bodies; if the latter, it is the type of union which is characteristic of the mind and body. But real qualities, since they are neither body nor mind, cannot be joined in either of these two ways.' *Traité*, 208/*Treatise*, 120–1.
25 *Traité*, 236–7/*Treatise*, 144.
26 *Traité*, 237–8/*Treatise*, 145.
27 *Traité*, 238/*Treatise*, 145.
28 He develops this argument in the next paragraph as follows: 'If the force which transfers . . . bodies could belong to them in such a way that the thing which is moved were itself the principle of its motion and this force were identical with it, then the notion of this force would have to include in its concept the idea of extension, as the other modes of body do. This is not the case. Therefore we have reason to believe that the force which moves is no less really distinct from matter than thought is and that it belongs as much as thought does to a spiritual substance.' *Traité*, 148/*Treatise*, 69.
29 *Traité*, 327/*Treatise*, 216.
30 'However since these two faculties [viz. perceiving and willing] are not distinct from the mind or the power of thinking, and since they are two streams which are inconceivable apart from their source, they are not really distinct from each other either, just as the shape and local motion of a body are not distinct from the body nor from its extension. Thus these two faculties are just the thing itself which thinks, which sometimes knows and sometimes determines itself.' *Traité*, 148/*Treatise*, 69.
31 *Traité*, 242/*Treatise*, 148.
32 *Traité*, 142/*Treatise*, 64.
33 *Traité*, 190/*Treatise*, 104.
34 *Traité*, 141–2/*Treatise*, 63.
35 *Traité*, 190/*Treatise*, 104.
36 *Traité*, 194/*Treatise*, 108.
37 *Traité*, 242/*Treatise*, 148.
38 *Traité*, 245/*Treatise*, 150.
39 *Traité*, 213/*Treatise*, 124. See Suárez, *Metaphysics*, Disputatio XVII, section ii, §21 (Vives edn., 1861), xxv. 591–2.
40 *Traité*, 213/*Treatise*, 124.
41 *Traité*, 235/*Treatise*, 143.
42 *Traité*, 327/*Treatise*, 216.

43 *Traité*, 141/*Treatise*, 63.
44 *Traité*, 136/*Treatise*, 58–9.
45 AT vii. 79.
46 '. . . *si aliunde quam a rebus corporeis emitterentur.*' AT vii. 79–80. The corresponding passage in the *Principia* refers to the various parts of matter which '*efficiunt ut varios sensus habeamur colorum, odorum, doloris, etc.*' AT viii-A. 40.
47 '. . . *alias facultates, ut locum mutandi.*' AT vii. 78.
48 AT vii. 177.
49 AT v. 222.
50 Descartes to Elizabeth, 21 May 1643; AT iii. 665.
51 Descartes to Regius, January 1642; AT iii. 503.
52 AT viii-A. 65.
53 AT viii-A. 66.
54 AT viii-A. 322.
55 AT viii-A. 322.
56 Gerauld de Cordemoy, *Six Discours sur la distinction & l'union du corps & de l'ame*, in *Oeuvres philosophiques*, ed. P. Clair and F. Girbal (Paris, 1968).
57 *Six Discours*, 135–6.
58 *The Search after Truth*, trans. T. Lennon and P. Olschamp (new edn., Cambridge, 1997), 450.
59 *Traité de la nature de la grace*, ed. G. Dreyfus; *Oeuvres complètes* (Paris, 1976), v. 66.
60 *Dialogues on Metaphysics and Religion*, ed. N. Jolly, trans. D. Scott (Cambridge, 1997), 59, 199.
61 *The Search after Truth*, 658.
62 Descartes to More, 15 April 1649; AT v. 347: 'Of course I do not think that any mode of action belongs univocally to both God and creatures, but I must confess that the only idea I can find in my mind to represent the way in which God or an angel can move matter is the one which shows me the way in which I am conscious I can move my own body by my own thought.' See Descartes to Elizabeth, 21 May 1643; AT ii. 666: 'It is in our own soul that we must look for these simple notions.'
63 In the Reply to Gassendi: 'I do not see what sort of thing you want existence to be, nor why it cannot be said to be a property just like omnipotence – provided, of course, that we take the word "property" to stand for any attribute or for whatever can be predicated of a thing.' AT vii. 382–3.
64 See D. Clarke, 'Malebranche and occasionalism: A reply to Steven Nadler', *Journal for the History of Philosophy* vol. 33 (1995), 499–504.
65 An earlier version of this paper was presented at the December 1995 Eastern Division meeting of the American Philosophical Association symposium in New York. I am grateful to the other symposiasts, Daniel Garber and Jonathan Bennett, for comments on the earlier draft.

7 The invention of nature

Descartes and Regius

Theo Verbeek

Descartes' *Le Monde* is more original than any of his other works – more original at any rate than the *Principia*, in which he adopts a framework which it would be more logical for him to reject. First of all, *Le Monde* is composed on an interesting plan. As Descartes explains in the *Discours*, it started with 'quite a full' exposition of what he understood about light. Then, 'as the occasion arose', he added 'something about the sun and fixed stars, because almost all light comes from them; about the heavens, because they transmit light; about planets, comets and the earth, because they reflect light; about terrestrial bodies in particular because they are either coloured or transparent or luminous; and finally about man, because he observes them'.[1] The scope of the treatise, therefore, was traditional but, in so far as all things were organised around the theme of light, the presentation was novel. The second original feature of *Le Monde* is that Descartes asks his readers to 'lose sight of all the creatures that God made five or six thousand years ago' and 'suppose that God creates anew so much matter all around us that in whatever direction our imagination may extend it no longer perceives any place which is empty'.[2] In the *Discours* the same is formulated as an invitation to 'leave our world wholly for them ['the learned'] to argue about and to speak solely of what would happen in a new world'.[3] Physics starts neither with experience nor with a review of existing opinions, but with an exercise of the imagination: 'Allow your thought to wander beyond this world to view another world – a wholly new one which I shall bring into being before your mind in imaginary spaces.'[4]

Neither the idea of organising physics around one particular theme (light) nor that of constructing a new world (instead of knowing the old one) are simply expository devices. As we learn from the *Discours* the 'method' of 1618–19 was first applied to mathematics proper (geometry and algebra), but the *Regulae* show that the problem of light was one of Descartes' priorities.[5] Light, as the vehicle of perception, bridges the gap between ourselves and the world; a mathematical treatment of light bridges the gap between the world of common experience (the world we see with our eyes) and the world as it really is (the world we think by means of mathematical concepts).[6] Finally, in the field of optics Descartes could boast of some real discoveries, which promised to be of practical interest.[7] The conventional explanation, on the other hand, of Descartes' use of the 'fable' of the reconstruction of the world is that in this way he concealed the revolutionary character of his views.[8] But even if that purpose explains some aspects of the *Discours*, it is not likely that before 1633 Descartes needed a similar strategy.[9] Moreover, according to *Le Monde*, the 'fable' was chosen not to conceal the truth but to make it better understood:

> In order to make this long discourse less boring for you, I want to clothe part of it in the guise of a fable, in the course of which I hope the truth will not fail to become sufficiently clear and will be no less pleasing to see than if I were to set it forth wholly naked.[10]

The most likely explanation therefore is that Descartes used it as an analytical tool. Still, we should be clear about what this means. It is not a tool of the kind used by, for example, Hobbes to elucidate the nature of political obligation; indeed, Descartes does not have recourse to a *resolutio* of a given object into its constituent parts but, while starting from ideas that are clearly and distinctly understood, constructs an object not given in experience.

The matter Descartes wants us to imagine is not infinite and perhaps not even indefinite, except in the sense that its size must be adapted to the capacity of our imagination.[11] Indeed, we must confine it to a 'determinate space which is no greater, say, than the distance between the earth and the principal stars in the heavens', although we may suppose that the matter that God created in fact 'extends indefinitely far beyond in all directions'.[12] By limiting the action of our mind we create a clear image of something virtually infinite: 'It is much more reasonable to prescribe limits to the action of our mind than to the works of God and we are much better able to do so.'[13] As a result, Descartes' explanation of the universe does not consist in rethinking the work of God but in creating a theoretical model:

> My purpose is not to explain, as [the philosophers] do, the things which are in fact in the real world but only to make up, as I please, a world in which there is nothing that the dullest minds are incapable of conceiving, and which nevertheless could be created exactly as I have imagined it.[14]

The imaginary character of the model is also emphasized in the next step. The only condition indeed is that we work with ideas that we know perfectly: 'Since we are taking the liberty of fashioning this matter as we fancy, let us attribute to it, if we may, a nature in which there is absolutely nothing that everyone cannot know as perfectly as possible.'[15] That is the reason why matter is conceived as 'a real, perfectly solid body which uniformly fills the entire length, breadth and depth of this huge space in the midst of which we have brought our mind to rest'.[16] It is divided in as many parts as we can think of:

> It is not that God separates these parts from one another so that there is some void between them: Rather, let us regard the differences he creates within this matter as consisting wholly in the diversity of the motions he gives to its parts. From the first instant of their creation, he causes some to start moving in one direction and others in another, some faster and others slower (or even, if you wish, not at all); and he causes them to continue moving thereafter in accordance with the ordinary laws of nature.[17]

Motion is local motion: 'I am not acquainted with any motion except that which is easier to conceive than the lines of the geometers – the motion which makes bodies pass from one place to another and successively occupy all the spaces which exist in between.'[18] All the time, however, imaginability remains the main requirement because only in that way we can be sure not to entangle ourselves in contradictions:

> Were I to put into this new world the least thing that is obscure, this obscurity might well conceal some hidden contradiction I had not perceived, and hence, without thinking, I might be supposing something impossible. Instead, since everything I propose here can be distinctly imagined, it is certain that even if there were nothing of this sort in the old world, God can nevertheless create it in a new one. For it is certain that he can create everything we can imagine.[19]

The aim of the science of nature is not to identify the ingredients God has actually used or the plan God has actually followed but to construct a possible world, which is possible for no other reason than that it can be imagined. An explanation of the world is an intelligible model of the world.

The assumptions Descartes later on makes about what actually is the case are limited to God: 'God, who is, as everybody knows, immutable, always acts in the same way.'[20] 'What more firm and solid foundation could one find for establishing a truth, even if one wished to choose it at will, than the very firmness and immutability which is in God?'[21] Laws of nature are based on the fact that God 'preserves all things by a continuous action and consequently [preserves] as much of it, not as it may have been some time earlier but precisely as it is at the very instant that he preserves it'.[22] Accordingly, the idea of God's immutability serves to remind us that even in a possible world something remains the same. The two types of arguments – one on possible worlds (possible because they can be imagined) and the other on the necessary features of any possible world (necessary because they derive from its supposed creator) – come together in the definition of *nature*:

> Note, in the first place, that by 'nature' I do not mean some goddess or any other sort of imaginary power. Rather, I am using this word to signify matter itself, in so far as I am considering it taken together with all the qualities I have attributed to it and under the condition that God continues to preserve it in the same way that he created it. For it follows of necessity, from the mere fact that he continues thus to preserve it, that there must be many changes in its parts which cannot, it seems to me, properly be attributed to the action of God (because that action never changes) and which therefore I attribute to nature. The rules by which these changes take place I call the 'laws of nature'.[23]

In the light of Descartes' later writings the most obvious interpretation of the combination of 'continued creation' and immutability would be that God's immutability compensates for the fact that the world has no real substance. In *Le Monde* however it is just the reverse: the reason why nature remains the same is that 'there must be many changes which cannot be attributed to the action of God'. The scientific significance, therefore, of God's immutability is that changes must be accounted for within nature itself: 'God alone is the author of all the motions in the world insofar as they exist and insofar as they are rectilinear; but it is the various dispositions of matter which render them irregular and curved.'[24] Accordingly, God's immutability creates the conditions for natural laws in the modern sense of the word, that is, laws that have the form of an equation.[25]

Again, it is tempting to complete the picture with elements from Descartes' later works – especially the *Meditationes* and the *Principia*[26] – but I believe that temptation should be resisted. In *Le Monde* Descartes makes no claims with respect to the essence of things, except to say that it is not necessary for them to have real qualities.[27] In fact, since judgments on essences are never made by the imagination, which is the main faculty used in *Le Monde*, but by the intellect, we cannot simply conclude on the basis of *Le Monde* that the essence of material bodies is extension or even that the question of the essence of bodies is relevant.[28] All we can say, therefore, is that 'nature' is used as a theoretical model, which imposes itself, not because we know or trust that it is a true picture of reality but because it is built from elements which we can readily imagine. The primary object of physics, therefore, can no longer be identified in experience: any object, any event may qualify as part of 'nature' provided it fits the parameters of the model. As a result, traditional distinctions, like those between natural and artificial things, natural and violent motion, heavenly and earthly bodies collapse. Inversely, man is no longer an object of physics, except in sofar as he can be seen as a moving body.[29]

Descartes connects this revolutionary way of defining the object of physics (which is basically a novel conception of physical explanation) with some more old-fashioned ideas, probably to preserve the unity of philosophy. Thus, for example, when summarising his earlier results in the *Discours de la méthode*, he seems to regret that he cannot speak of man in the same way as of the world, that is, by 'showing from what seeds and in what manner *nature* must produce them'.[30] As if the model of matter in motion can ever apply to the behaviour of organisms and as if the world reconstructed in *Le Monde* is a machine. After all, even a mechanical machine has some sort of inherent teleology or functionality, which is clearly lacking from *Le Monde*. Similarly, in the *Météores* Descartes sets out to explain the 'nature of things', or what he will later call the 'essential form' of things – a question which, as we have seen, is conspicuously absent in *Le Monde*.[31] In fact, Descartes is too much a traditional philosopher to accept the conceptual independence of physics which a strict interpretation of *Le Monde* would imply. Accordingly, there is a certain ambiguity in his conception of physics which is illustrated by the contrast between *Le Monde* and the *Principia* (1644). The *Principia* (1644) unfold following a thoroughly traditional plan, which makes them look almost trivial, whereas the approach suggested by *Le Monde* would eventually culminate with Newton's *Principia mathematica* (1687). Much of this ambiguity becomes evident in the work of Descartes' immediate successors, some of whom are completely traditional, while others seem to grasp the true nature of the Cartesian project, sometimes, for that matter, for purely external reasons. In this article I concentrate on Henricus Regius, the first explicitly Cartesian professor in the Low Countries.

Henricus Regius (1598–1679) had no official post at the university – he was town doctor of Utrecht – but since the university of Padua had given him the degree of doctor in philosophy he was entitled to give private lectures, and it is for these that he needed a 'compendium of physics'.[32] This he wrote immediately after he had read Descartes' *Météores* and *Dioptrique*.[33] It made him so successful that he was rewarded a professorship '*extra ordinem*' in theoretical medicine and this in turn led to a turbulent association with Descartes himself.[34] Although from the beginning there were signs of disagreement, Regius was faithful and loyal.[35] He submitted all his writings to Descartes and accepted his verdict most of the time.[36] Still, he had a mind of his own and wanted to speak it. The book he had been working on ever since he first knew Descartes – the nucleus of which was the *compendium* mentioned earlier – was ready in 1645 and was published the following year.[37] Descartes dissociated himself publicly from Regius in the strongest terms.[38]

Regius quite often uses Cartesian concepts but most of the time he avoids using Cartesian arguments, even in his early writings.[39] The concept of nature, as it is developed in *Fundamenta physices*, is of particular interest, not only because of its ambivalence in Descartes himself but also because Regius apparently knew *Le Monde*, which Descartes had sent him in 1641.[40] According to Regius the object of physics are 'natural things', that is, things that possess a 'nature'. 'Nature' on the other hand is defined as an 'internal and corporeal principle of action, passion and cessation'.[41] It is body and whatever pertains to body, like mind – Regius prefers the Cartesian term *mens* to the more traditional *anima* – which 'cannot have sensations, imaginations and various other things without the body'.[42] Mind is an object of physics; God, the angels and 'other similar things' have an incorporeal principle of action, passion and cessation, and are not.[43] Regius' concept of 'nature' cannot be dissociated from what he calls the most common law of nature or, also, the 'general affection of things natural'. That is that in virtue of God's concurrent power (*per divinam concurrentem potentiam*) everything 'remains as much as it can in the same state, until it is disturbed by something else'.[44]

Nature is twofold: it is the matter of natural things and it is their form. The matter of natural things is body as such (*corpus simpliciter*) or body in general (*corpus universe consideratum*) or also, as Regius says, what others call body insofar as it is body (*corpus quatenus corpus*).[45] It is what water, earth, plants, animals and all other natural things are made of, all in the same manner, namely, by the disposition of their parts.[46] Regius then proceeds to define the essence of matter as three-dimensional extension (*extensio in longum, latum et profundum*). All other qualities (hardness, softness, colour, taste, fragrance, etc) do not belong to the essence of matter. Experience teaches us that all those things can be removed from material bodies:

> For hard things can become soft; soft things hard; coloured things can lose their colour; savoury things their taste; fragrant things their fragrance. But without extension a body would soon cease to be a body for it would no longer be an extended substance. Indeed, whatever is substantial to it would completely be lost for it would be neither an extended nor an unextended substance and those are all the substances that exist.[47]

Extension does not need a subject to support it. Extension as such can exist by itself (*per se subsistere potest*). It is not an accident; indeed, it is the very being of the body (*ipsissima corporis essentia*). Matter is substance and can exist by itself. It is a perfect substance if only because there are no imperfect substances, that is, substances that would not be able to exist by themselves.[48]

Form on the other hand is that which together with matter constitutes a perceptible thing. There is general form and there is special form. The general form, which is normally called material form is the specific configuration (*comprehensio*) of movement (or rest), situation, figure and quantity of parts that is necessary to form a particular thing. To constitute a form more than one accident is needed, which may be the reason why Regius speaks of *comprehensio*. Thus, for example, the smallness of the particles of water cannot constitute its form; they must also be long, thin, flexible, etc. These principles constitute the material form. Indeed, what we see in natural things is that if these principles are right the things are right, too; but that if they are not right, things work badly or not at all – a functional criterion to which we shall have to return.[49] In any case, these principles allow us to dispense with all other qualities and natures. Again, we should look at all these qualities together. The form of a thing is 'effective' only in conjunction with its movement, as we see in various machines and mechanical instruments.[50] In a sense therefore form is accidental to matter – matter can be conceived without form – but essential to bodies:

> How this is possible can be shown in a watch, in which the movement, figure, situation and size of the parts are accidental to the iron but essential for the watch; for the iron would be iron without them but the watch would not be a watch without them.[51]

Special forms are human minds. Regius deals extensively with mind and mental processes in ch. 12, but already in ch. 1 the fundamental ambiguity of his concept of 'form' comes to light. It is in virtue of the special form together with the general form that man is what he is.[52] Accordingly, the human body has a (general and material) form, by which it is what it is, but on top of that it has a second (special and immaterial) form, which is the mind:

> [Mind] cannot be reduced to the general or material form for it cannot result from the movement, rest, size and situation of parts. We understand quite easily how an ingenious disposition of parts can produce a wonderful machine, which, in virtue of the movement, situation, figure and size of its parts, performs certain actions; but that by the same principle it could be conscious of its acts and would be able to think would be incomprehensible.[53]

In an earlier disputation this passage was immediately followed by the logical (although as it is formulated highly ambiguous) conclusion that from the conjunction of body and mind does not result an *unum ens per se* but only *per accidens*.[54] It triggered off the *querelle d'Utrecht*, undoubtedly because it was interpreted in Averroist or neo-Platonist fashion as that man actually consists of three parts: a body, a soul and a mind, the mind being part of an impersonal mind and the soul being some sort of vital principle.[55] In the original version of *Fundamenta physices*, as it was first submitted to Descartes, Regius had made things even worse by claiming that we can say almost nothing on the mind:

> So far as the nature of things is concerned, the possibility seems to be open that the mind can be either a substance or a mode of a corporeal substance. Or, if we are to follow some philosophers, who hold that extension and thought are attributes which are present in certain substances, as in subjects, then since these attributes are not opposites but merely different, there is no reason why the mind should not be a sort of attribute co-existing with extension in the same subject, though the one attribute is not included in the concept of the other. For whatever we can conceive of can exist. Now it is conceivable that the mind is some such item; for none of these implies a contradiction. Therefore it is possible that the mind is some such item.[56]

Accordingly, Regius moved to the sceptical position that we cannot know at all whether the mind as such is material or immaterial; indeed, even if extension and thinking are attributes these do not necessarily belong to different substances – a claim which, needless to say, Descartes scornfully rejects.[57]

Composition is not Regius' strongest point. Thus, for example, it is only towards the end of the ch. 1 that he makes a distinction which, one would say, it would have been logical to make at the beginning: some natural things are 'spontaneous' and others 'arbitrary'. Spontaneous are those which, without human intervention, display action, passion or cessation; arbitrary those which operate only by human intervention. The first are also called 'natural' (in the narrow sense of the word), whereas the second are also called 'artificial'. This distinction between things that are natural and things that are artificial should be the primary division with which the whole discussion starts, but, then, no doubt under the influence of Descartes, Regius does not like this distinction. So-called artificial things are in fact natural things; they, too, have an internal principle of action, passion and cessation, which depends on a specific configuration and movement of the particles. To produce an artefact all we have to do is apply active forces to passive things, more or less in the same way as when we sow corn or breed mules.[58] Accordingly, there is only a difference of degree between artificial and natural things: 'Even the vilest creatures as they are born every day are so wonderfully made according to the laws of mechanics that our most ingenious *automata* cannot compare with them.'[59]

In fact, much of the text of *Fundamenta physices* comes from earlier disputations and from the lecture notes Regius circulated among his students.[60] The part on nature, too, can be traced back in this way. Thus, we read in the second of the series *De illustribus aliquot quaestionibus physiologicis* that nature is an internal principle of action, passion and cessation; that it is corporeal; that it consists of matter and form, etc.[61] But despite the fact that Regius had received a copy of *Le Monde* in the early summer of 1641, the influence of that treatise is noticeable only in the cosmological parts of his disputations. Moreover, the official motive for a discussion of ‘nature’ is that it is much talked of in medicine.[62] This medical background explains some other features of *Fundamenta physices* as well. Thus, for example, it is undoubtedly a functional or physiological (in our sense of the word) point of view that explains Regius’ claim that, ‘if these principles [i.e., the ‘primary’ qualities that make up the general form] are in good order the thing is in good order and if these are in bad order the thing functions badly or not at all’.[63]

It is also the medical point of view that explains the distinction, very prominent in most of Regius’ work, between perceptible parts (*partes sensibiles*) and imperceptible parts (*partes insensibiles*). In *Fundamenta physices* this distinction is made immediately after the definition of matter as extended substance.[64] *Physiologia* presents it almost immediately after the definition of physiology as the theory of the healthy body.[65] Since health (*sanitas*) is a disposition of the parts of the human body it is logical to proceed with a definition of ‘part’ (a part is a corporeal substance which makes the body *apt to perform certain actions*) and to distinguish parts into those that are perceptible (*sensibilis*) and those that are imperceptible (*insensibilis*). Indeed, ‘without [imperceptible parts] no account can be given of acerbity [*acrimonia*], mildness [*lenitas*], volatility, coarseness; and an infinite number of other qualities; whereas if you admit those parts all can be intelligibly explained’.[66] Accordingly, the original meaning of the distinction between sensible and insensible parts is to provide a theoretical foundation for the concept of health.[67] Severed from their medical context, imperceptible parts come back in *De illustribus aliquot quaestionibus physiologicis* and *Fundamenta physices*.[68] They are too small to be sensed (*propter exiguitatem aut parvitatem sensus fugientes*).[69] Still, many of them together make up a sensible part, more or less in the way in which many colourless silk threads make up a coloured piece of cloth.[70] In a very Cartesian way they are not atoms but indefinitely divisible.[71]

In a general way Regius seems to have followed a pre-existing plan. This is clear, not only in the book as a whole, whose overall structure is thoroughly traditional, but also in details, especially if we consider separately the parts from which it is composed. The *Physiologia*, for example, follows the traditional model of physiological textbooks, which goes back to Jean Fernel (1486–1577) and ultimately Galen. Regius starts with the parts of the human body, discussing the fundamental properties of the insensible parts from which they are constituted, and goes on with temperament, ages, faculties, etc. In his ‘Physiologia’, which forms the first section of *Universa Medicina*, Fernel too successively discusses bodily parts, elements, temperaments, spirits and innate heat, faculties, functions and reproduction.[72]

Then, there are some concepts which do not belong to either a mechanical or a traditional framework. As we saw earlier, Regius defines nature as an internal and corporeal *principium agendi, patiendi et cessandi*.[73]

In classical Latin *cessatio* is synonymous with *defectio*, *requies* or *terminus*.[74] In Descartes' *Principia* it is used only once:

> For example, a man sitting on board a ship which is leaving port considers himself to be moving relative to the shore which he regards as fixed; but he does not think of himself as moving relative to the ship, since his position is unchanged relative to its parts. Indeed, since we commonly think all motion involves action, while rest consists in the cessation [*cessationem*] of action, the man sitting on deck is more properly said to be at rest than in motion, since he does not have any sensory awareness of action in himself.[75]

In fact, Descartes rejects the vulgar idea of rest ('we commonly think'), according to which there would be a natural 'cessation' of action: his position therefore would be the exact opposite of Regius. This is clear from another passage:

> We live on the Earth, whose composition is such that all motions occurring near it are soon halted, often by causes undetectable by our senses. Hence from our earliest years we have often judged that such motions, which are in fact stopped by causes unknown to us, come to an end of their own accord. And we tend to believe that what we have apparently experienced in many cases holds good in all cases – namely, that it is in the very nature of motion to come to an end [*ex natura sua cessare*], or to tend towards a state of rest. This of course is utterly at variance with the laws of nature; for rest is the opposite of motion and nothing can by its own nature tend towards its opposite or towards its own destruction.[76]

Since Regius never uses the concept of *cessation* except to define nature, it is difficult to see what he means with it. Elsewhere I suggested that he borrowed the term from Sébastien Basson.[77] Basson also starts by defining nature as 'an internal principle by which, as long as it is and continues to be, any thing has the power to act and to suffer as well as to cease the same'.[78] Basson specifically describes *cessatio* as the natural process by which a thing ceases to act or to undergo changes:

> For we see that the animal stops growing; that it stops acting; that it stops going; that it stops being warm. Similarly we see plants and herbs stop growing, stop greening, stop flourishing, all of which happens by some internal faculty. Indeed, the question we are examining is what this internal principle of motion and immobility [*status*] of things is.[79]

Basson never returns to the subject.[80] All one can say, therefore, is that it reads like a vitalist re-interpretation of the Aristotelian definition of nature as the cause and principle of motion *and rest*.[81] Why Regius takes this notion of nature from Basson is not clear at all, except that along with Gorlaeus, Gassendi, the Bootii and others, Basson was known as an anti-Aristotelian.[82] In any case, the notion of *cessatio* strikes an odd note in connection with Regius' first and most general law of nature, according to which it is explicitly impossible that motions 'naturally' come to an end:

> Nothing is contrary to itself, nor can anything be destroyed except by its adversary. And this is evident in the situation, figure, mass and many other aspects of natural things, all of which remain unchanged until they are taken away from them by some adversary power.[83]

Regius' formula is almost identical with Descartes', but there are important differences. First of all, instead of making an appeal to God's immutability, Regius believes that the law can be based on experience. But then Regius seems to interpret the law primarily as dealing with the static properties of bodies, like situation, figure and mass, although later on he also applies it to to moving bodies.[84] At any rate, Regius indiscriminately applies it to both quantitative and qualitative problems. Thus, for example, he uses it to explain why the living body and the soul remain together: 'The bond that keeps the soul conjoined with the body is the law of the immutability of nature, according to which everything remains in its present state as long as it is not disturbed by anything else.'[85]

This takes us to the question as to what may or may not be Cartesian in Regius' work. Let us first concentrate on method. In his last letter to him Descartes blames Regius for not doing enough to prove his position; that his way of presenting his views, 'through definitions and divisions' and 'by proceeding from the general to the particular', may be right for disputations but is not suitable for books, where one should prove and demonstrate, especially if the views one proposes are controversial.[86] It may have been one of the few points on which Descartes agreed with his great adversary Gysbertus Voetius (1589–1676), who also insisted that Regius should prove his opinions by solid demonstrations.[87] Descartes' characterisation of Regius' method is more or less right. The way Regius starts a discussion is generally by presenting a division between, say, A and B, then to define A and discuss the various ingredients and implications of A, finally to return to B and deal with it in the same manner. Although this scheme, which is probably of Ramist origin, is more visibly present in the disputations than in the books, it remains very characteristic throughout Regius' career.

Descartes' second way of characterising Regius' method, as 'proceeding from the general to the more particular', is also more or less correct. In the *Physiologia*, for example, Regius starts with a definition of medicine and the different parts of medicine, which leads him to define health as the principal object of physiological knowledge, and that in turn leads to a discussion on perceptible and imperceptible parts.[88] Descartes' own method is based, at least in the *Regulae* and in *Le Monde*, on the postulate that something can be explained only by reducing it to something that is already understood. Part of that method therefore is to make an inventory of what is already understood and to see in what way this can be used for understanding the things that as yet are not understood. Accordingly, problems present themselves, not in a 'natural' order, but in an epistemological order, that is, in the order in which they are understood.[89] It is for that reason that theoretical models count as 'explanations', in spite of the fact that nothing is 'explained' in the sense that a specific 'cause' is assigned to a specific event.

Regius' method, on the other hand, is problem-oriented. In the second edition of *Fundamenta physices* (then called *Philosophia naturalis*) he describes his method as follows:

> When in physics a problem is proposed for solution, we must first think of an intelligible cause by which the effect considered in the problem could be aptly and intelligibly produced. Next we must look around whether there is some other cause that is more suitable and should be preferred to the first; but it must be equal and equally productive as the first. If nothing can be found we must be satisfied with the earlier solution as long as we find no alternative that is as good or better.[90]

Method is a three stage process: the formulation of a problem; the identification of a cause such that it can serve as an intelligible explanation of the effect described in the problem; and the elimination of alternative causes, so as to show that no better explanation is available.[91] In a way, that is, of course, also the method used by Descartes himself in the *Principia*, where he tries to show not only that he has a solution for all traditional problems of philosophy – at least those that seem worthwhile – but also that his solution is superior to the traditional solution.[92] But it was not the method of *Le Monde*, in which Descartes ignores all the things one can know and all the questions one can ask to concentrate on a few clear and distinct ideas – a task facilitated by the fiction of the recreation of the world and later by systematic doubt. In fact, that is also the main methodological difference between *Le Monde*, in which a new world is imagined on the basis of ideas that are not given in experience, and *L'Homme*, in which real beings (animals and men) are presented as if they are machines.[93]

But there is still another aspect to Regius' method, and that is that any explanation is valid only as long as no better explanation is found. As a result, no explanation is definitive. Something like that is implied in Regius' valedictory letter to Descartes of July 1645:

> To be frank, many people are convinced that you have done much to discredit your philosophy by the publication of your metaphysics. You promised nothing but clear, certain and evident things; but these first essays [*débuts*] make them feel that all is obscure and uncertain and the discussions with able men you have had with respect to these essays all but reinforce their doubt and uncertainty. It is no good to point out to them that your reasonings are as you promised them to be. For their answer is that any enthusiast, any atheist, any fool can claim the same thing about his own absurdities.[94]

According to Regius, the criterion of clearness and distinctness is not a criterion for truth. The causes identified by an explanation are by definition clearly and distinctly understood but 'clearness' and 'distinctness' are not absolute properties of ideas: an idea is 'clear and distinct' if it brings the mind to rest, that is, if it is more clear and more distinct than the other ideas one can think of. Accordingly, Regius rejects the concept of ultimate and definitive explanation, which is so prominent in the later Descartes.

This is also the underlying issue in the *'programma'* of 1647, which consists of theses extracted from ch. 12 of the first version of *Fundamenta physices* – that is, the version originally submitted to Descartes and altered by Regius to pacify his irascible friend.[95] For, although the subject is man and the mind of man, the issue is whether the conclusion that these are attributes of two ontologically different substances can be justified. According to Regius it is a *magnus paralogismus*, because what is simply different is not necessarily opposite. The very fact that extension and thought can be attributed to the same subject (man) shows that they cannot be contrary, because the definition of 'contrary' is that it cannot be attributed to the same thing at the same time.[96] Accordingly, God could have made the world in such a way that mind is either a mode of an extended substance or that, along with extension, mind as an attribute belongs to the same substance, although we know, on the grounds of Biblical evidence, that such is not the case.[97]

Finally, Regius clearly rejects Descartes' metaphysics. Differences over metaphysical problems are present even in the first extant letter of Descartes to Regius.[98] The reason may be that Regius did not understand Descartes' metaphysics, but it is more likely that he did not feel the need for it, given that he rejects the concept of ultimate explanation (which is possible only if the identity of evidence and truth can be metaphysically justified). Inversely, if in his later work Regius is led to deal with metaphysical problems (like the existence of God or the immortality of the soul), it is to point out that they are theological rather than philosophical. In fact, he consistently solves them by lavish quotations from the Bible. Still, there is not much reason to believe, as Baillet suggests, that this is meant to reconcile his Orthodox Utrecht enemies.[99] In fact, by relying entirely on

Biblical evidence Regius admits that these questions cannot be solved by natural means, a view Voetius rejected.[100]

Regius' physics raises at least two problems. The first is whether a Cartesian physics is possible without a metaphysical foundation; and the second, whether it can be presented on a traditional format. For an answer we can go to Descartes himself. Metaphysics may have helped him in writing *Le Monde* – as he himself claims – but one cannot say that metaphysics is very important in *Le Monde*.[101] In fact, the only explicitly metaphysical thesis that figures in it is that of the immutability of God, whose only role however is to eliminate theological and metaphysical speculations from physics.[102] Accordingly, an unmetaphysical presentation of Cartesian physics is certainly possible. The answer to the second question is given by the *Principia*, which were meant to show that Descartes has a better answer to all traditional problems of philosophy.[103] Even so, Regius' *Fundamenta physices* strikes the reader as hybrid: Regius rewrites traditional philosophy and medicine, and provides new answers to old problems, instead of formulating old problems in a new way or indeed raising new problems. The result resembles neither *Le Monde* with its revolutionary view of physics, nor the *Principia* with its, in a way equally revolutionary, marriage between physics and metaphysics. From the viewpoint of the history of philosophy the most interesting point is possibly the complete disappearance of Descartes' first concept of 'nature' – nature, not as the totality of what is given in experience, but as a theoretical model; in the end, even Descartes himself found that unattractive, presumably because he was not prepared to give up the unity of philosophy. Perhaps the only Cartesian who did understand something of that problem was not Henricus Regius but his student Johannes de Raey (1622–1702).[104] Even so, de Raey was led to question the traditional concept of nature only under the negative impulse of Spinoza. The idea that there are no limits either to intelligibility or to causality made it necessary to raise the separation of philosophy, on the one hand, and practical and religious concerns, on the other, to a conceptual level, and to make it impossible to use the language of philosophy (that is, the language of mathematics) to refer to things and events that are given in experience.[105]

Notes

1 *Discours* AT vi. 42.
2 *Le Monde*, AT xi. 32. The conventional view was that the world was created in 4004 BC; cf. Jacques-Bénigne Bossuet, *Discours sur l'histoire universelle* (Paris, 1966), ch. 1.
3 *Discours*, AT vi. 42. The phrase 'to leave our world wholly for them to argue about' is an allusion to the erroneous but proverbial *Vulgata* translation of Eccl 3: 11 (*mundum tradidit disputationibus eorum*).
4 *Le Monde*, AT xi. 31.
5 *Discours*, AT vi. 19–20; *Regulae*, VIII, AT x. 394–5; 402.

6 Cf. Nancy L. Maull, 'Cartesian optics and the geometrization of nature', *Review of Metaphyics*, vol. 32 (1978–9), 253–73.
7 Descartes' discovery of the anaclastic line allowed a new way of cutting lenses; it took him a very long time, however, to find a lens grinder to realise his ideas; cf. *Discours*, AT vi. 77; cf. *Dioptrique*, X, AT. vi. 211–27. It seems that with the help of Constantijn Huygens Descartes at last found someone in Amsterdam who could do it.
8 *Discours*, AT vi. 42.
9 See *Discours*, VI, AT vi. 75.
10 *Le Monde*, AT xi. 30. For a general interpretation of Descartes' use of the fable as a stylistic and moralistic device, see Jean-Pierre Cavaillé, *Descartes et la fable du monde* (Paris, 1991); Guido Canziani, 'Histoire autobiographique e fable del mondo tra le Regulae e le Discours,' in Giulia Belgioioso et al., eds., *Descartes: Il metodo e i saggi: Atti del Convegno per il 350° aniiversario della publicazione del Discours de la méthode e degli Essais* (Rome, 1990), i. 163–84.
11 As far as I can see, the technical distinction between infinite and indefinite appears for the first time in the context of the *Meditationes*; cf. Descartes to Regius, 24 May 1640, AT iii. 64; *Primae Responsiones*, AT vii. 113–14; *Principia*, I, 26–7, AT viii-A. 14–15.
12 AT xi. 32.
13 AT xi. 32–3.
14 AT xi. 36.
15 AT xi. 33.
16 AT xi. 33.
17 AT xi. 34.
18 AT xi. 40. For earlier criticism of the Aristotelian concept of motion, see *Regulae*, XII, AT xi. 426.
19 AT xi. 36.
20 AT xi. 38.
21 AT xi. 43.
22 AT xi. 44.
23 AT xi. 37.
24 AT xi. 46.
25 Cf. Peter Damerow et al., *Exploring the limits of pre-classical mechanics* (New York/Berlin, 1992); J.A. van Ruler, *The Crisis of Causality: Voetius and Descartes on God, Nature and Change* (Leiden, 1995).
26 For the use of the word 'nature' in the *Meditationes* and the *Principia*, see K. Murakami, M. Sasaki, T. Nishimura, *Concordance to Descartes' Meditationes de prima philosophia* (Hildesheim, 1995); Franco Aurelio Meschini, *Indice dei Principia Philosophiae di René Descartes* (Firenze, 1996).
27 *Le Monde*, I–IV, AT xi. 3–23.
28 Probably the question of the essence of material bodies is as little relevant to *Le Monde* as that of the essence of light is to *Dioptrique*; see AT vi. 83.
29 The idea of extending the original project, so as to include man (not simply as a perceiver of light, as which man is an object for optics, but as a self-regulating machine) probably is a late development; see Descartes to Mersenne, June 1632, AT i. 254–5; *Correspondance du P. Marin Mersenne* (Paris, 1969), iii. 314–15.
30 *Discours*, AT vi. 45–6.
31 *Météores*, AT vi. 231–9; cf. Descartes to Regius, January 1642, AT iii. 506. This, too, seems to be a late development; see Descartes to Mersenne, 5 April 1632, AT i. 242–3; *Correspondance de Mersenne*, iii. 291.
32 Regius' biography can be reconstructed from J.G. Graevius, *Oratio in obitum viri clarissimi et celeberrimi Henrici Regii* (Utrecht, 1679); some additional

elements can be found in M.J.A. de Vrijer, *Henricus Regius: De eerste 'cartesiaansche' hoogleeraar aan de Utrechtsche Hogeschool* (The Hague, 1917); C. Louise Thijssen-Schoute, *Nederlands Cartesianisme* (Amsterdam, 1954: reprinted, Utrecht, 1989); see also my 'Regius's Fundamenta physices', *Journal of the History of Ideas*, vol. 55 (1994), 533–51.

33 Descartes, *Epistola ad R.P. Dinetum*, AT vii. 582–3.

34 A professor 'extra ordinem' is best compared with a 'Reader' or an 'Associate Professor'. Regius became an 'ordinary' professor in 1639.

35 Descartes sent Regius the first version of the *Meditationes* but was disappointed by Regius' reaction; see Descartes to Regius, 24 May 1640, AT iii. 63–70.

36 As early as 1641 he wanted to publish a book of his own – called presumably *Prodromus novae philosophiae* – but cancelled it at the request of Descartes; see my 'Regius's Fundamenta physices.'

37 *Fundamenta physices* (Amsterdam, 1646). It was reprinted as *Philosophia naturalis* in 1654 and 1661.

38 'Lettre-préface de l'édition française des Principes', AT ix-B. 19. For the evolution of their relation before and after 1647, see my 'Le contexte historique des Notae in programma quoddam', in Theo Verbeek, ed., *Descartes et Regius: Autour de l'Explication de l'Esprit humain* (Amsterdam, 1993), 1–33.

39 *Physiologia sive cognitio sanitatis* (Utrecht, 1641); *De illustribus aliquot quaestionibus physiologicis* (Utrecht, 1641); *Responsio in appendicem* . . . (Utrecht, 1642). An earlier disputation on the circulation of the blood is not relevant in this context.

40 Descartes to Regius, May 1641, AT iii. 374; that the 'book' promised in this letter is *Le monde* is shown in 'Regius's Fundamenta physices.'

41 '*Natura est internum corporeumque agendi, patiendi et cessandi principium.*' *Fundamenta physices*, I, 1.

42 '*Per principium internum et corporeum intelligo non tantum ipsum corpus; sed quidlibet etiam quod ullo modo ad corpus pertinet. Sic mens est principium internum corporeum; quia sensationes, imaginationes, et alia plurima sine corpore peragere non potest.*' *Fundamenta physices*, I, 1.

43 *Fundamenta physices*, I, 1. '*Alia similia*' is probably meant to include the mind insofar as it is not just the subject of perception but an immortal being.

44 '*Generalis omnium rerum naturalium affectio, quae pro communissima earum lege haberi potest, quod per divinam concurrentem potentiam, unumquodque ad illas pertinens, quantum potest, in eodem maneat statu, donec inde ab alio deturbetur.*' *Fundamenta physices*, I, 1.

45 Ibid, 2.

46 Ibid, 2.

47 Ibid, 2.

48 Ibid, 3.

49 Ibid, 5.

50 Ibid, 5.

51 Ibid, 6.

52 'Forma specialis est mens humana: quia per eam, cum forma generali in materia corporea existente, homo est id quod est.' Ibid, 29. Same formula in *De illustribus aliquot quaestionibus physiologicis*, III, 8 (these disputations are not paginated; references are to parts and sections).

53 *Fundamenta physices*, I, 29; similar formula in *De illustribus aliquot quaestionibus physiologicis*, III, 8.

54 *De illustribus aliquot quaestionibus physiologicis*, III, 9.

55 See my article 'Le origini della querelle d'Utrecht', *Giornale critico della filosofia italiana*, Series VI, vol. XII, anno LXXI (1992), 276–88

56 The original version was restored in the 'programma' (1647) which Regius

wrote in reaction to Descartes' denunciation of him. The text is known from a Utrecht medical disputation, *Medicatio viri cachexia leucophlegmatica affecti* (Utrecht 1647) and from Descartes' reply, *Notae in programma quoddam*, AT viii-B. 342–3; see my 'Le contexte historique des Notae in programma quoddam'.

57 *Notae in programma quoddam*, AT, viii-B. 347–52.

58 The argument had been suggested by Descartes; Descartes to Regius, January 1642, AT iii. 504; cf. Regius, *Responsio sive Notae in Appendicem ad Corollaria [. . .] Voetii* (Utrecht, 1642) 18. For the general argument, see J.A. van Ruler, *The Crisis of Causality*.

59 *Fundamenta physices*, I, pp. 45–6. On this point the second edition is not much better than the first, although on the whole it is a bit more balanced and certainly more explicit; cf. *Philosophia naturalis*, 2nd edn., I, 1–15, pp. 1–70, which roughly corresponds with the first chapter of *Fundamenta physices*.

60 The lecture notes were never found, but the quotations in Schoock's *Admiranda methodus* (based on a copy obtained from Anna Maria van Schuurman's brother Johan-Godschalk) show that much was recycled in *Fundamenta physices*.

61 *De illustribus aliquot quaestionibus physiologicis*, II, 2, 3, 5, etc.

62 Ibid, 1.

63 *Fundamenta physices*, I, 5.

64 Ibid, 3.

65 '*Sanitas est dispositio partium humani corporis actionibus recte performendis apta*.' *Physiologia*, I, i, 3, p. 1.

66 *Physiologia*, I, i, 4–5, p. 1.

67 The distinction between perceptible parts and imperceptible parts is one of the points that continually comes back in contemporary criticism. Schoock, for example, citing passages from Regius' lecture notes, enjoys making fun of the imperceptible parts, which, for that matter, he believes the Cartesians have stolen from Democritus; cf. *Admiranda methodus novae philosophiae Renati Des-Cartes* (Utrecht, 1643) III, cap. 6, 212–23 (*Querelle*, 288–92); cf. 'introductio', p. 4 (*Querelle*, 182–3).

68 *De illustribus aliquot quaestionibus*, II, 9–13; *Fundamenta physices*, I, 3–4.

69 *Fundamenta physices*, I, 3.

70 Ibid, 4; cf. *De illustribus aliquot quaestionibus*, II, 1.

71 *Fundamenta physices*, I, 4; '*Haec non est indivisibilis, nec semper ejusdem magnitudinis aut figurae, sed quantum ad talia, idem de ipsis quod de reliquis corporis est putandum*.' *Physiologia*, I, i, 5, p. 1; '*Hae non sunt atomi, sed indefinite divisibiles; nec semper ejusdem sunt magnitudinis aut figurae; sed quantum ad talia, idem de ipsis quod de reliquis corporibus est dicendum*.' *De illustribus aliquot quaestionibus*, II, 11; see also Schoock, *Admiranda methodus*, III, 6, p. 216 (*Querelle*, p. 292), quoting from Regius' lecture notes.

72 See Fernel, *Universa Medicina*, ed. Joh. and Otho Heurnius (Utrecht, 1656). Fernel's plan was also adopted by Heurnius himself, whose *Institutiones* Regius used in his medical lectures; cf. J.G. Graevius, *Oratio in obitum Henrici Regii*, 16.

73 *Fundamenta physices*, I, 1; *De illustribus aliquot quaestionibus*, II, 2.

74 Cicero, for example, uses it to refer mockingly to Epicurus' ideal of imperturbability as idleness or inactivity: 'Epicurus, quasi pueri delicati, nihil cessatione melius existimat.' Cicero, *De natura deorum*, I, 37, 102. *Cessatio* is never used as a technical term.

75 *Principia*, II, art. 24, AT viii-A. 53; cf. Meschini, *Indice dei Principia*, 36.

76 *Principia*, II, art. 37, AT viii-A. 63. This article contains the classical expression of the law of inertia; it had been anticipated by Isaac Beeckman; cf. Alexandre Koyré, *Études galiléennes* (Paris, 1968), 107–10; Frédéric de Buzon and Vincent Carraud, *Descartes et les Principia II: Corps et mouvement* (Paris, 1994), 100–1.

77 *Descartes and the Dutch*, 104. Little is known about Basson. Brucker rightly calls his work 'lectu dignissima' (*Historia critica philosophiae*, 2nd edn., Leipzig, 1766, vol iv., 467–8). See Karl Laßwitz, *Geschichte der Atomistik vom Mittelalter bis Newton* (2 vols., Hamburg/Leipzig, 1890), i. 467–81; Tullio Gregory, 'Sebastiano Basso', *Giornale critico della filosofia italiana*, 3rd series, vol. 18 (1964) 38–65; C.H. Lüthy, 'Thoughts and Circumstances of Sébastien Basson. Analysis, Micro-history, Questions', *Early Science and Medicine*, vol. 2 (1997), 1–73 (many new details).

78 Basso, *Philosophia naturalis adversus Aristotelem Libri XII in quibus abstrusa Veterum Physiologia restauratur et Aristotelis errores solidis rationibus refelluntur* (Geneva, 1629/Amsterdam, 1649), 1.

79 *Philosophia naturalis adversus Aristotelem*, 3.

80 *Cessatio* is mentioned again on p. 163, but in a way which does not add anything to what was already known.

81 '*Natura est principium et causa motus et quietis in eo in quo inest, primo per se et non secundum accidens.*' Gisbertus ab Isendoorn, *Physiologia peripatetica* (Deventer 1643), 34; cf. Adriaan Heereboord, *Philosophia naturalis* (Amsterdam, 1665: first edn. Leiden, 1663), 18. The definition goes back to Aristotle's *Physica* (II, 1).

82 Pierre Gassendi, *Exercitationes paradoxicae adversus Aristoteleos* (Grenoble 1624); David Gorlaeus, *Exercitationes philosophicae* (Leiden 1620); Arnold and Gerard Bootius, *Philosophia naturalis reformata* (Dublin 1641). Basson and Gorlaeus are cited by Voetius as notorious anti-Aristotelians (*Querelle*, 98, 100, 101, 109, 112, 113). In the Low Countries the Bootii enjoyed special fame because they were of Dutch origin.

83 *Fundamenta physices*, I, 1. There is no analogous formula in the disputations, so we must assume that Regius took it from Descartes' *Principia*, II, art. 37, AT viii-A. 63, quoted above.

84 '*Ut materia universi, a Deo creata, in eo statu in quo est ex lege immutabilitatis naturae perpetuo manet; ita motus, in creatione variis materiae universi partibus certa quantitate inditus, perseverat, ex eadem lege, in eodem quantitatis gradu. Et ut nullum corpus, nisi per accessum vel decessum materiae antea existentis augetur vel imminuitur; ita nullum mobile, nisi per accessum vel decessum motus antea exsistentis, magis vel minus moveri incipit vel desinit. Atque ut materiae partes ab uno corpore in aliud possunt transferri, et, quamdiu non transferuntur, ibidem ex lege universali manent; ita motus ab uno mobili in aliud mobile potest transire et quamdiu non transivit in eodem subjecto ex eadem lege esse perseverat.*' *Fundamenta physices*, I, 8. Note that in this context Regius uses the word immutability – which he did not use when he first formulated the law.

85 Quoted in *Notae in programma quoddam*, AT viii-B. 344 and refuted by Descartes, ibid, AT viii-B. 357.

86 Descartes to Regius, July 1645, AT vi. 248–9.

87 *Querelle*, 90. Naturally, what Voetius calls 'solid demonstrations' are in fact syllogisms.

88 *Physiologia*, I, i, 1–5, p. 1.

89 *Discours*, AT vi. 18–19.

90 *Philosophia naturalis*, ed. 1654, 441.

91 This concept of method is very similar to the one proposed by Henricus Reneri (1593–1639), another Utrecht friend of Descartes, in his Utrecht inaugural lecture *'de lectionibus et exercitiis philosophicis'*, in *Illustris Gymnasii Ultrajectini Inauguratio* (Utrecht, 1634), 165–200. Descartes dissociates himself from it in the sixth part of the *Discours*.

92 See my article 'Les Principia dans la culture néerlandaise du XVII^{e} siècle', in Giulia Belgioioso and Jean-Robert Armogathe, eds., *Descartes: Principia Philosophiae (1644–1994)* (Naples, 1996), 701–12.

93 Cf. *Discours*, AT vi. 45–6.
94 Regius to Descartes, 23 July 1645, AT iv. 255. The text is known only in the French translation of Baillet (ii. 269–71).
95 See my 'Le contexte historique des Notae in programma quoddam' and 'Regius's *Fundamenta physices*'. The *'programma'* was composed by Regius either alone or in conjunction with a student, Petrus Wassenaer (died 1688). Wassenaer remained a life-long friend of Regius, who at one stage planned to leave him his manuscript remains; cf. De Vrijer, *Regius*, 75.
96 Regius, *Brevis explicatio mentis humanae [. . .] a Notis Cartesii vindicata* (2nd edn., Utrecht, 1657), 18.
97 See the original text of the *Programma*, as it is copied by Descartes himself in *Notae in programma quoddam*, AT VIII-B. 542–3. The Biblical evidence quoted in *Fundamenta physices* (246) includes Eccl 12: 9; Mat 17: 3; Luke 16: 9; 16: 22; 24: 43; II Cor 5: 8; 12: 3–4; Apoc 6: 9–10.
98 Descartes to Regius, 24 May 1640, AT iii. 63–70.
99 Baillet, ii. 268.
100 Cf. Voetius, 'De ratione humana in rebus fidei', *Disputationes theologicae selectae*, vol. i (Utrecht, 1648), 1–12.
101 'I think that all those to whom God has given the use of this reason have an obligation to employ it principally in the endeavour to know him and to know themselves. That is the task with which I began my studies; and I can say that I would not have been able to discover the foundations of physics if I had not looked for them along that road.' Descartes to Mersenne, 15 April 1630, AT i. 144; cf. Descartes to Mersenne, 6 May 1630, AT i. 149–50; 27 May 1630, AT i. 151–4.
102 See above. If the role of the immutability of God is to prevent any outside interference with the model, one might as well suppose that God does not exist: physically speaking the hypothesis of a God that does not exist (or does not interfere) and of a God that intervenes in a constant way are equivalent.
103 *Letter to Father Dinet*, AT vii. 580; see also the letters to Mersenne of 1640–1.
104 See my 'Tradition and novelty: Descartes and some Cartesians', in Tom Sorell, ed., *The Rise of Modern Philosophy* (Oxford, 1993), 167–96; 'Les cartésiens face à Spinoza: le cas de Johannes de Raey', in Paolo Cristofolini, ed., *L'hérésie spinoziste/The Spinozist heresy* (Maarssen, 1995), 77–88.
105 See Johannes de Raey, *Cogitata de interpretatione* (Amsterdam, 1692).

8 The influence of Cartesian cosmology in England

Peter Harrison

Introduction

On the evening of 14 January 1706, William Nicolson of Carlisle, Divine and Fellow of the Royal Society, recorded in his diary details of a conversation held that day with the Earl of Carbury, the topic of which had been the various cosmological theories which had been proposed over the course of the previous twenty years: 'This brought us into a Discourse about the several Systemes of Dr. Burnet, Dr. Woodward, etc., and his Lordship ingeniously enough observ'd that, since Des Cartes led the way Every New Philosopher thought himself wise enough to make a World.'[1] In fact, there was little ingenuity in Carbury's observation. In attributing credit (or in this case more probably blame) to the person of Descartes for having inspired English theories of the earth, Carbury was actually rehearsing what was then a widely held view. Fellow Clergyman Robert Jenkin had written in 1700 that Descartes' system of the world 'was the first Ground and Occasion to all the rest'; Newtonian John Keill similarly identified Descartes as 'the first world maker this Century produced', while John Edwards, a conservative champion of the geocentric view, complained that English cosmogonists had taken '*Copernicus* or *Cartes* to be better writers than *Moses*'.[2] There is little doubt, then, if contemporary witnesses are to be believed, that Descartes' hypotheses concerning the formation of the earth exerted a considerable influence on English cosmologies in the late seventeenth century. Even writers who had explicitly abandoned key elements of the Cartesian cosmology came to be regarded in some sense as his followers.

In this chapter I shall examine the reception of Descartes' cosmology in England, with a view to determining the extent of his influence on various 'theories of the earth' put forward in the latter half of the seventeenth century. A particular focus will be the question of whether cosmology was to be a hypothetical or historical enterprise, an issue on which Descartes and his English imitators are generally thought to differ. In light of this discussion, I hope to provide a revised reading of Descartes on this question, and will conclude that the French philosopher was more sensitive to demands that cosmology harmonise with sacred history than is commonly thought to be the case.

Seventeenth-century cosmologies[3]

Descartes' cosmogony first came to public notice in the *Principia philosophiae* (1644), although its central ideas had already been set out in the ill-fated *Le Monde*, a work written in the years 1630–2, but not published in Descartes' lifetime. In Part III of the *Principia* Descartes gives a hypothetical account of how the cosmos might have been formed by matter and motion. Corpuscles of a single kind, jostling against one another, gave rise to three kinds of material: the first, the matter of the sun and stars; the second, the matter of the heavens; the third, the matter of earth, planets and comets.[4] The heavens organised themselves into vortices with stars at their centres.[5] The planets of our world system, originating in smaller vortices of their own, were captured along with their satellites in the vortex of the sun. The origin of the earth receives its own treatment in Part IV. Our own planet, once a sun, consisted of a core of stellar material, enclosed by two concentric crusts separated by a layer of water (Figures 8.1a and b). Initially a perfect sphere, the earth took on its present appearance when the outer crust dried and cracked. Great blocks of this desiccated outer layer then tilted into the watery abyss below, forming the present oceans and continents with their mountain ranges.

Descartes was at pains to stress the hypothetical nature of these conjectures: 'I do not wish it to be believed that the bodies of this visible world were ever created in the manner which was described above. . . . The world was not formed in that way in the beginning, but was created directly by God.'[6] Certainly, on the face of it, Descartes' cosmogony is not consistent with the order of events set out in the creation narratives of Genesis. Surprisingly, then, it was precisely the possibility of squaring the Cartesian hypothesis with the sacred history of the earth, as presented in scripture, which excited the imaginations of Descartes' first English admirers, and attracted them to his theory of the earth. The first to see potential applications of the Cartesian cosmology to sacred history was Platonist Henry More. Thomas Burnet subsequently adopted Cartesian ideas to explain both the origins of the world and its demise, and after him William Whiston and John Woodward, while rejecting the central elements of the Cartesian thesis, were attracted by the idea that a scientific account of the world's origins, such as Descartes had given, could corroborate sacred history.

Henry More was one of the leading Cambridge Platonists, and for a period in the middle decades of the seventeenth century was an enthusiastic, if not always uncritical, advocate of Cartesian philosophy.[7] While he was later to become disenchanted with the French philosopher, he played a

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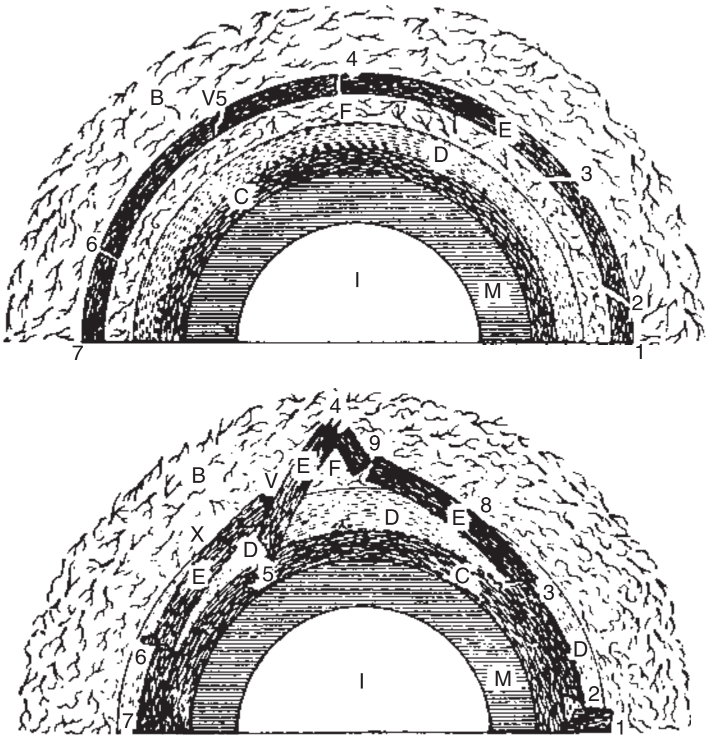

Figure 8.1 Descartes' illustration of the formation of continents and oceans. *Principia*, Plate XVIII. Figure 8.1a shows layers I and M, the earth's innermost core. Layers C and E are the concentric crusts, separated by D (liquid) and F (vapours). In Figure 8.1b, the upper crust has cracked and tilted giving rise to a continent (8), a mountain range (4) and oceans (3, 6).

a vital role in the introduction of his ideas to England, and continued to lecture on the *Principia* at Cambridge long after his initial enthusiasm for Descartes had waned.[8] While More's early advocacy of Descartes' ideas is well known, his role in the introduction of Cartesian cosmology into English circles has largely gone unnoticed. It was More's conviction that Descartes had single-handedly revived a natural philosophy which had originally been spelt out in the book of Genesis, but which, owing to a combination of misrepresentation and neglect on the part of the Greek philosophers (who by and large had plagiarised their philosophy from Moses), had long since sunk into oblivion.[9] The only vestige of true philosophy to have survived this cavalier treatment was to be found in the philosophy of Plato. In More's view, the significance of the advent of Cartesian philosophy was that the secrets of creation hitherto hidden in the writings of Moses could now once again be revealed. In the preface to *A Collection* *of Philosophical Writings* (1662), he wrote that the truths of Platonism and Cartesianism 'were ever lodged in the *Tent* of *Moses*'. He continued, 'such rich Theories have been treasured up, though men have not had, for these many Ages, the leisure or opportunity of unlocking them till now'.[10] In *The Defense of the Threefold Cabbala*, published in the same year, More gave specific details: the three different kinds of matter to which Descartes alluded may be found in Genesis;[11] that the earth was once a sun 'seems plainly to be contained in *Moses*, but is at large demonstrated in *Des Cartes* his Philosophy';[12] and again, 'here the *Suns* and *Planets* are plainly said to be *generated* by the *Heavens* or *Aethereal Matter*, which is again wonderfully consonant to the *Cartesian Philosophy*'. More concludes that 'the *Mosaical* Philosophy in the Physiological part thereof is the same with the *Cartesian*. . . . I should look upon Descartes as a man more truly *inspired* in the knowledge of Nature than any that have professed themselves so this sixteen hundred years'.[13]

More was also concerned to show that the Cartesian philosophy could shed light not only on the natural principles at work in the formation of the world, but also on the physical mechanisms which would bring about its destruction. The earth, he predicted, would grow old and exhausted: 'And the more it is exhausted, the nearer still it will be wrought towards the Sun, according to the *Cartesian* Philosophy.' Having been caught up in the vortex of the sun, the whole earth would ignite, and be consumed by fire. Thus the conflagration of the earth, as predicted by scripture, was confirmed by the philosophy of Descartes.[14]

In linking scientific cosmology to both creation narratives and prophecies concerning the timing and manner of the earth's demise, More established the pattern which Burnet and Whiston were to follow. Thomas Burnet (1635?-1715) entered Clare Hall in 1651 and was soon drawn into the orbit of the Cambridge Platonists, adopting their openness to the new philosophy, their novel approach to biblical exegesis, and their willingness to entertain theological conceptions of doubtful orthodoxy. In 1681 Burnet published what was destined to become one of the most remarkable works of its time, *Telluris Theoria Sacra*, which outlined, in its author's own words, 'the original of the earth, and all of the general changes which it hath already undergone or is to undergo till the consummation of all things'.[15] The work actually set out a simplified version of the Cartesian cosmogony, which focused upon the Deluge and the final conflagration of the world.[16] The elegant Latin of the original version, praised by no less a personage than Charles II, was to become in translation a masterpiece of English prose. Indeed, a number of critics archly observed that its success was owing more to its style than its substance.

Burnet's theory of the earth differed from that of Descartes in a number of respects. First, he ordered the layers of the earth according to their density. At the centre was not fire, but earth. Surrounding the core was a collection of 'terrestrial liquors', and above this layer of liquids, a dust-laden atmosphere (Figure 8.2a). Descartes' original five layers were thus reduced to three. In Burnet's scheme, the atmospheric dust settled upon the surface of the waters, drying into a thin, and perfectly smooth, shell. It was on this seamless outer crust that the first living creatures and our original parents lived out their lives in Edenic bliss. Their paradisal existence was to be short-lived, however. As time passed, the heat of the sun dried out the thin surface of the earth, as in the Cartesian theory. In addition, the sun's heat penetrated the crust to heat the liquors beneath, agitating them and producing vapours and exhalations. As Burnet describes subsequent events (Figure 8.2b), the shell of the world

a

b

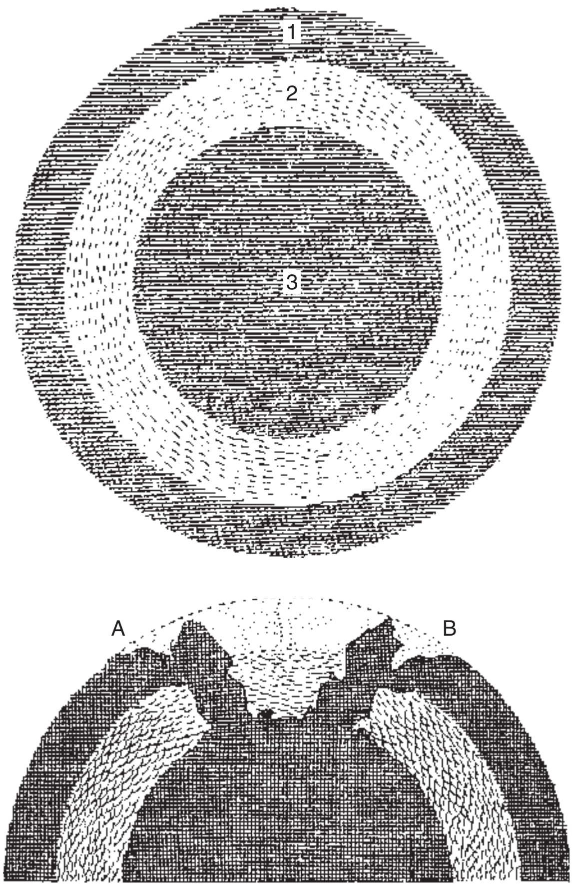

Figure 8.2 Burnet's illustration of the formation of the earth. *Sacred Theory of the Earth*, 2nd edn. (London, 1691). In Figure 8.2a, the crust (1) and core (3) are separated by a fluid layer (2). Figure 8.2b shows the fracturing of the outer layer, some of which collapses into the ocean beneath, forming oceans, continents, and mountain ranges.

> grew more dispos'd to a dissolution. . . . And at length, these preparations in Nature being made on either side, the force of the appointed time was come, that the All-wise Providence had design'd for the punishment of a sinful World, the whole fabric brake, and the frame of the Earth was torn in pieces, as by an Earthquake; and those great portions or fragments, into which it was divided, fell down into the Abysse, some in one posture, some in another.[17]

This, then, the biblical deluge, transformed an ideal antediluvian world into the present earth, pockmarked with mountains, awash with seas, sitting crooked on its new axis, its soils ruined by the salt of the inundating flood, and its inhabitants subjected for the first time to the vicissitudes of seasonal change and to a host of other inconveniences: it was now a fit home for a sinful human race.

Burnet's description of the final conflagration, unlike that of More, owes little or nothing to Descartes. In fact, Burnet specifically rejects two hypotheses of the final conflagration based on the Cartesian cosmology: first, that adopted by More, of the earth's being drawn too close to the sun; second, the possibility of the outbreak of the earth's central fire.[18] Rather, says Burnet, the final conflagration of the world will come about through the simultaneous eruption of volcanoes, the ignition of the earth's subterranean reserves of sulphur and bitumen, and a raining down of fiery meteors. 'Let us imagine', says Burnet,

> . . . all the Volcano's of the whole Earth, to be prepar'd and set to a certain time; which time being come, and a signal given by Providence, all these Mines begin to play at once; I mean, All these Fiery Mountains burst out, and discharge themselves in flames of fire, tear up the roots of the Earth, throw out hot burning stones, send out streams of flowing Metals and Minerals, and all other sorts of ardent matter, which Nature hath lodg'd up in those Treasuries. If all these Engines, I say, were to play at once, the Heavens and the Earth would seem to be in a flame, and the World in an universal combustion.[19]

Burnet's speculations about the origins of the earth and its subsequent changes stimulated others to similar conjectures. In 1695 John Woodward published his *Essay Toward a Natural History of the Earth,* a work followed in the next year by William Whiston's *New Theory of The Earth.* Despite an abrasive personality and an almost universal unpopularity, Woodward rose from humble beginnings to the elevated status of Professor of Physic at Gresham College in 1692. In the following year he was elected Fellow of the Royal Society. Like Burnet, he believed that the biblical deluge was the single most important event in determining the state of the present earth. The Flood, rather than the initial creation of the world, thus became his primary focus. Woodward argued on the basis of his field observations of rock strata and fossil beds that the whole earth was 'dissolved' during the deluge, the waters of which, as in the hypotheses of Burnet and Descartes, originated from beneath the crust. Sediments were laid down in the aftermath of the flood, ordered according to their specific gravity. This accounted for the distribution of fossils within rock strata. The layered rocks so formed were tilted to form the present mountain ranges. Though inspired by Burnet's work, the theoretical basis of Woodward's *Essay* lies elsewhere, in the writings of Nicolaus Steno.[20] Of the theorists under consideration, he has fewest affinities with Descartes, but Whiston was to incorporate a number of his ideas into his own treatise.

William Whiston was the brilliant young mathematician who succeeded Newton in the Lucasian Chair of Mathematics at Trinity. As an undergraduate at Cambridge he had encountered Burnet's *Sacred Theory*, and had penned juvenile essays on its contents.[21] Several years later, he was to revisit the Mosaic history of the creation, this time armed with the more potent Newtonian theory of gravitation. Set out in the manner of Newton's *Principia*, Whiston's *New Theory of the Earth* was remarkably ingenious, and certainly more imaginative than Woodward's plodding *Essay*. It begins and ends the world's history with a comet, and punctuates it in the middle with that same celestial body. The ancient chaos to which Moses and other ancient writers had referred, according to Whiston, was nothing other than a comet – 'a mixed compound of all sorts of Corpuscles, in a most uncertain confus'd and disorderly State'.[22] The earth was formed when this comet was drawn from its eccentric path into a stable orbit around the sun. As in previous theories, various layers formed around a hot central core, according to their relative densities. Whiston, like Burnet, thought the constitution of the earth to have been like an Egg: the central solid was analogous to the yolk; the great abyss to the white, and the habitable earth to the shell.[23] Unlike Burnet, however, Whiston held that the primeval earth had much the same topographical features as the present earth. The continents floated on their liquid substrate, as in the now familiar theory of isostasy, with denser parts of the crust sinking more deeply to form valleys and plains, and lighter regions floating higher to create mountains and plateaux.[24] The biblical deluge was visited upon the earth through the transit of another comet. Vapours from its tail inundated the earth, while its proximity destabilised the crust, allowing the waters beneath to add their volume to those which had fallen from the heavens. Eventually, the flood waters drained away or evaporated into the atmosphere, leaving behind the present oceans. With predictable symmetry, the earth's history was also brought to a close by a comet, possibly the same one which had brought the deluge. Heated by its approach to the sun, the comet would collide with earth bringing about its conflagration. Even after the death of the world by fire, these fiery bodies would still play a role in the scheme of things. Whiston speculated that following the destruction of the earth, the damned would most probably be housed in a comet, the variations in temperature as it approached and receded from the sun being such as to ensure their perpetual discomfort.[25]

Reactions to the theories of the earth

These cosmogonies aroused a variety of reactions, for the most part hostile. Burnet, in particular, being in a sense the first in the series, created something of a splash, his *Sacred Theory* and the later *Archaeologiae Philosophicae* attracting well over twenty refutations between them. But the reactions were by no means exclusively negative. The fact that the works were published at all is significant, for it indicates that they had successfully obtained ecclesiastical imprimatur.[26] Newton, with whom Burnet corresponded, seemed to react to the *Sacred Theory* quite positively, entering into the spirit of things and suggesting additional hypotheses.[27] Charles II was an equally famous, if less convincing advocate of Burnet's theses. Whiston sought, and received, the approval of Richard Bentley and Christopher Wren for the manuscript of his *New Theory*. Most important of all, however, was the verdict of Sir Isaac Newton, 'on whose principles it depended and who well approved of it', according to Whiston's memory of events.[28] However, it was Woodward's more conservative piece which received more praise and less approbation than any of the others.

More important for our present purposes were the more numerous negative reactions. These tended to fall into a well established pattern. Prior to the modern period there had been three philosophical accounts of the world's origins which were thought to compete with the biblical doctrine of Creation: the Epicurean/Lucretian thesis, according to which the world had its origins in chance collisions of atomic particles; the Stoic doctrine of an endless cycle of worlds punctuated by conflagration and regeneration; and the Aristotelian view which asserted the eternity of the world.[29] The presumed defect of the Epicurean view was that it attributed the formation of the world to chance, while the Stoic philosophy, it was thought, left all to a fatal necessity: the former denied God's creative design, the latter, his ongoing providence.[30] The situation with Aristotle was a little more complex. Aristotle's view was generally conceded to be consistent with the truths of reason, its deficiency being that it contradicted the truths of revelation. The scholastics had thus allowed that God might have created the world from all eternity – it was in his power to do so. However, from the scriptures it was known that God had created the world in time, or as Augustine would have it, with time.[31] Aristotle could be forgiven this unfortunate lapse, however, for his philosophy still called for a first cause of motion, a feature famously exploited by Aquinas, and his causal explanations placed great store on final causes, thus allowing his Christian interpreters to discover in the natural world numerous instances of providential design. Aristotle's only blemish, then, was to have asserted the eternity of the world, a position which contradicted scripture. Many critics of More, Burnet, Whiston, and Woodward (and by implication Descartes as well), simply aligned the new theories with the old, and rehearsed traditional objections. Novel cosmological speculations were classified variously as Epicurean, fatalistic, inconsistent with traditional interpretations of scripture, or some combination of these three.

The Latitudinarian Bishop of Worcester, Edward Stillingfleet, for example, declared that the Cartesian hypothesis was 'as precarious and groundless as the Epicurean'. John Keill demanded to know how Burnet's opinion 'differs from the *Epicureans*'.[32] Whiston was accused of having introduced a fatal necessity into his scheme, such that 'from the Necessity of the Motion of the Comet and Earth, [the Deluge] must have happen'd whether Men had repented or not; and so induces a *rigid fatality*'.[33] A related, if more conservative, variation on this line of criticism took its point of departure from Descartes' abandoning of the quest for final causes. The denial of final causes was linked to assertions, common to the various theories of the earth, that our world was not the centre of the cosmos and that there might be other inhabited worlds than ours. To remove the earth from its central position, to make its birth later in time than that of the universe, to concede that other worlds may be populated – all seemed to cast doubt upon the privileged place of the human being in the general scheme of things, and to impugn God's special providence and care purportedly evidenced in the act of creation. Edward Howard observed, albeit against the rising tide of opinion, that 'by undoubted Astronomical Observations 'tis certainly prov'd that the Earth is in the centre of the Universe'. Assertions to the contrary would make our home 'a diminutive Brat engendered by Seeds descending from the Skies'.[34] In his *Brief Remarks on Mr Whiston's New Theory of the Earth*, John Edwards agreed that if the theorists were correct, then 'this terrestrial Globe is a despicable Spot, a Speck, a Point in comparison of the Vast and Spacious Conjeries of the Sun and Fixed Lights'.[35] Summing up the various aspects of this line of criticism, Edwards wrote that the world was not the result of a 'lucky hit of Atoms', and it was in vain that 'the *French Philosopher*' had attempted to give 'an account of all the Phaenomena of the visible World from matter and mere Mechanical Motion'. The heliocentric view was 'contrary to the verdict of our senses', and 'Man' is 'the Centre of the World in respect of Final Causes'.[36] The common features of the theories of the earth – the Copernican hypothesis, the new corpuscular philosophy and the Cartesian assertion of the futility of the search for final causes – came to be regarded by many as a combination potentially fatal to the quest for beneficent adaptations in the created order, a quest which from the middle of the seventeenth century was to play a central role in English natural theology and science.[37]

Not only was it alleged that the theorists had excluded divine providence. They were also charged with having contradicted scripture – the error of Aristotle. The Rev. William Nicolson, with whose diary entry this paper began, referred disparagingly to ‘Dr Burnet’s roasted egg, Dr Woodward’s hasty pudding’, and ‘Mr Whiston’s snuff of a comet’, observing: ‘Our late refiners upon the Creation and Deluge are unanimously agreed, that the old interpreters of Moses were all block heads’.[38] Whiston, said John Edwards, ‘contradicts the plain history of the first inspired penman’. Burnet was accused by Keill of having ‘openly rejected the History of the formation of the earth as it is delivered by *Moses*’.[39] John Arbuthnot, in a response to Woodward’s piece, wrote that ‘Compilers of Theories’ should ‘have more regard to *Moses’s* relation, which surpasses all the accounts of Philosophers’.[40]

The speculative nature of the new theories of the earth also drew sustained criticism. A number of critics, apparently inspired by the spirit of Baconian empiricism, objected to the overly hypothetical nature of these enterprises. Thomas Robinson sneered at those ‘that have undertaken to entertain the World with new *Schemes* and *Theories* of the Earth, without having been Ten Foot under Ground’.[41] Robert St. Clair, sometime associate of Robert Boyle, derided ‘these men of *Ephesus*, whose trade it is to make shrines to this their *Diana* of hypothetical philosophy, I mean who in their Closets make Systems of the World, prescribe Law to Nature, without ever consulting her by Observation and Experience’.[42] Edward Howard remarked that ‘if we confide on the Principles of Des-Cartes, we must rely on fictitious Inventions, instead of warrantable experience’.[43] In his critique of Whiston, John Edwards ridiculed theories of the earth as pure fantasy: ‘It is a mere *Romantick* strain that this *Earth* of ours was once a *Sun*, and that all the World was *Heavens* at first. . . . The world of *Whirlpools* is a World of *Monsieur Des Cartes’s* own making.’[44] As we can see, the myth of Descartes as an armchair scientist – a myth which has yet to be fully dispelled – emerged as early as the seventeenth century in English reactions to the Cartesian cosmology and its domestic offspring.[45]

More considered critiques focused on difficulties with the details. It was pointed out, for example, that while Burnet and Whiston might have managed to cover the surface of the earth with water relying on natural causes alone, they had to avail themselves of supernatural assistance to be rid of it.[46] Woodward, too, was justifiably accused of having relied upon supernatural assistance when his ingenuity in attributing events to second causes was exhausted.[47] John Keill, who was the most able critic of the theorists, combined elements of all these criticisms. Of Burnet he wrote that ‘it was his unhappiness to begin at first with the *Cartesian* philosophy’, a system which Newton had shown to be ‘absolutely false’. Cartesian speculations had led to ‘strange schemes and unaccountable fancies’. Against Whiston and Burnet he argued that ‘it was Moses’ intention to be understood in a real and literal meaning’, and theories which departed from this were thus false. Finally, returning to the common refrain, the theorists were charged with ‘deducing the origin of the Universe from Mechanical principles’ – the mark of the sect of the Cartesians – thereby giving 'ignorant atheists ... some plausible pretences for their incredulity'.[48]

In all of this, the one persistent line of criticism voiced by virtually every commentator was the incipient Epicureanism of the theories. In the eyes of their critics, the theorists had deduced the formation of the earth from either chance or necessity, and more specifically, from the principles of matter and motion alone. The Deity was denied any active role: neither providential guidance nor miraculous interpositions seemed admitted by the theorists despite their protestations. This was the baleful, all-pervading influence of Descartes, conspicuous even in the theories of Whiston and Woodward, who had long since dispensed with the central features of the Cartesian hypothesis. Following Descartes, they had diminished the role of the central actor in the drama of creation, and presumed to make worlds of their own.

Creation and cosmology

Having given a brief consideration to English theories which in one way or another owed something to the Cartesian model, and to their reception, it is worth returning to the question of their reliance on Descartes. Jacques Roger has made a convincing case that English theorists 'misunderstood' Descartes. The 'comparison of the Cartesian narration with the biblical one', he writes, was 'the first distortion of the Cartesian model'. According to Roger, Descartes was concerned to elucidate the formation of the world in some atemporal sense; the English theorists were interested in history.[49] While Roger has made an important distinction here, in my view the situation is more complex than this. I believe that the differences between Descartes and his English appropriators turn out to be not as great as they might at first seem, and we what find is not so much a fundamental difference of orientation, but rather a difference of emphasis. There are four issues to be considered.

The first point that can made relates directly to the criticisms which we have just outlined. What emerges most clearly from these is that the 'Cartesianism' of which the theorists were accused was not primarily to do with Descartes' hypothetical order of events and its relation to the biblical sequence of creation, but rather with the Cartesian mode of explanation. Thus, while there were those who took umbrage at the theorists' apparently cavalier treatment of Moses, of more fundamental concern to critics were the theorists' attempts to describe all the features of the world in terms of secondary causes. It was for this reason that Whiston and Woodward, despite having explicitly rejected the Cartesian sequence of events, were nonetheless typically depicted as Cartesians (at least in their cosmogonies). This common feature of the possible world of Descartes and the historical worlds of the theorists is most conspicuous in their shared efforts to reduce the incidence of supernatural interventions into the ordinary operations of their respective worlds. Descartes supposes in *Le Monde* that 'God will never perform any miracle in the new world, and that the intelligences, or the rational souls, which we might later suppose to be there, will not disrupt in any way the ordinary course of nature'.[50] More, in discussing the final conflagration of the earth, notes that there are second causes 'that are sufficient for such ministries as this'.[51] In Burnet's writings this reluctance to invoke direct divine activity becomes an important explanatory principle: 'We must not Flie to Miracles, where Man and Nature are sufficient.'[52] Whiston agreed that divine providence operates within 'the setled Course of Nature' without the need for 'a miraculous interposition on every occasion'.[53] All of these accounts thus evidence a concern to refashion traditional understandings of God's relation to the world, suggesting that the Deity's involvement with his creation is manifested neither in the initial design of individual features of the created order, nor in ongoing interventions into its operations, but rather in the wisdom of the natural laws which govern the universe and its productions.[54] It was precisely this diminishing of the possibilities for direct divine interventions in the creation and governance of the world that led to the 'Cartesian' hypotheses being identified as Epicurean.

The second point which needs to be made concerns what Roger calls the inevitable comparison of the Cartesian narration with the biblical one. Roger implies that in 'comparing' the Cartesian account with the biblical ones, English theorists were misreading Descartes' cosmology as a history – a history which demanded either a harmonisation with Genesis or a frank admission that they were in fundamental conflict. Again, this way of reading the English cosmogonies is misleading. The key comparison for these writers was not Descartes and Moses, but Descartes and Aristotle, and following on from this, whether a Cartesian or Peripatetic philosophy would shed more light on the biblical account of creation.[55] Cartesian philosophy did not provide a parallel creation narrative, but rather a means of interpreting Moses philosophically. This concern is most apparent in More's work. In *Conjectura Cabbalistica*, the aim of which is to provide an interpretation of the first three chapters of Genesis, Descartes' *Principia* furnishes the key to unlock the true, if somewhat obscure, meaning of the author of Genesis. It is not the historical order of events that More is interested in, but what 'physiology' is common to both Descartes and Moses. Thus at the outset he states quite unapologetically that 'the most learned have already agreed that the whole Creation was made at once'.[56] More thus assumed, correctly, that Descartes believed in an instantaneous creation, and that Moses and Descartes alike had set out a temporal sequence of events in order to make their philosophy more intelligible.[57] For More, the historical question is immediately put to the side.

With Burnet, the case is different, for he clearly wishes in some sense to reconcile the Cartesian hypothetical account of the origin of continents and mountain ranges with the Biblical story of the Deluge. But Burnet's is only a partial historicisation. The creation of the universe is not a part of history, for as Burnet points out, we have no evidence on which to construct such a history.[58] However, it is not the case here, as Roger assumes, that 'Cartesian general cosmogony becomes merely a theory of the earth'.[59] Rather, Burnet distinguishes between those things about which we have useful historical evidence, and those about which we do not. The former is the purview of the historians, the latter the realm of hypothesis. If Burnet's interest is primarily historical, he does not thereby rule out the sphere of the hypothetical. Descartes, however, had begun to impinge upon history, and for this reason his creation myth was historicised by Burnet.

Third, the claim that English theorists read Descartes and Genesis as histories of the same event assumes not only that English readers misconstrued the Cartesian hypothesis, but equally that they interpreted the first chapters of Genesis as history as well. However, it was by no means clear that they did so. Certainly prior to the modern period, historical readings of the creation narratives were the exception rather than the rule. Patristic and Medieval commentators had typically relied upon the cumbersome apparatus of four-fold interpretation, a hermeneutical approach in which the literal sense was frequently buried beneath layers of allegory and tropology. Admittedly such allegorical readings had fallen from favour by this time, owing largely to the animus of the Protestant Reformers to the equivocal readings which they associated with Rome.[60] But the moderns could still argue that certain texts, and in particular those with implications for science, had been 'accommodated' by their authors to the capacities of their original audience. At any rate, there was a long tradition of non-historical readings of Genesis.[61] Augustine had proposed in the fifth century that the world had been created in an instant, despite the six-day sequence set down in the first chapter of Genesis.[62] The Augustinian position was subsequently reinforced by the fourth Lateran Council (1215) which declared that God created everything 'at the beginning of time simultaneously from nothing'. This idea, according to Edward Grant, 'was probably the most widely-held opinion on the creation during the middle ages'.[63] There were variations on this theme – that God could have created the world in an instant but had instead adapted his method of creation to human understanding, or that Moses, in recounting the creation of the world, had relied upon the six-day sequence to impress certain theological points upon his audience.[64] All in all, in the history of interpretion of the creation narratives, there was considerable support for the view that Moses' description of the creation, or more strictly, descriptions of the creation, are rather like explanatory models, not to be taken as a literal chronology of events.

When we look to the writings of the English theorists we find a degree of reluctance to read the first chapters of Genesis literally. As we saw earlier, More advocated an instantaneous creation. He also stated quite flatly that the 'story of the Creation, by being insisted upon in the most literall sense, has further'd Atheism in the world'.[65] Burnet agreed: 'Those who strictly adhere to the very Letter and Words of Moses, in his History of the Creation, give a handle to Atheists for their reproaches and cavils against the sacred Scripture.' The story of creation, he insisted, was an allegory or fable.[66] Burnet and Whiston both relied on the accommodation theory. According to Burnet, the Mosaic account of creation 'bears in it the evident marks of an accommodation and condescension to the vulgar notions concerning the form of the world'. He was more forthright in the Latin *Archaeologiae philosophicae* (1692), in which he informs his readers that Moses had 'only spoken popularly to comply with the dull Israelites, lately slavish brickmakers, and smelling strong of the garlic and onions of Egypt'. The six-day creation had been set forth 'to humour these ignorant blockheads that . . . had no sense nor reason in their thick skulls'.[67] Whiston, while insisting that the 'Literal Sense of the Sacred Scriptures ought not, without great Reason be eluded or laid aside', nonetheless conceded that 'Scripture did not intend to teach men Philosophy, or accommodate itself to the true and Pythagorick [i.e. heliocentric] System of the World'. He, too, made much of the modest intellectual resources of the ancient Israelites, whom, he noted, 'were very low and mean, and their improvements very small, or rather none at all in Philosophick Matters'.[68] We may conclude that as far as More, Burnet, and Whiston were concerned, Moses and Descartes alike had presented their philosophy in the guise of historical narrative, and the more transparent philosophy of the latter could be used as a key to access the more obscure and implicit philosophy of the former. The Mosaic 'history', in other words, needed to be decoded, for behind his condescending manner the real, which is to say, philosophical, truth might be discerned.

The final line of argument, which follows on directly from this last point, comes from the French philosopher himself. In Descartes' correspondence we encounter two intriguing passages which imply that he wished his cosmogony to be related to the biblical account of creation. In 1646, two years after the appearance of the Latin version of the *Principia*, Descartes wrote to William Boswell:

> I am about to describe the birth of the world, in which I hope to comprehend the greatest part of physics. And I will tell you that after four or five days, in re-reading the first chapter of Genesis, I have found, as if by a miracle that it can all be explained according to my imagination. . . . My new philosophy is in much better agreement with all the truths of faith than that of Aristotle.[69]

From this we might surmise that Descartes really believed, as did More and Burnet, that his theory of the formation of the world could be squared with the Genesis account without difficulty. Moreover, Descartes explicitly states what was evident to his English admirers – that his philosophy was more consistent with the Christian doctrine of creation than that of Aristotle. Descartes seemed thus to concede that the hypothetical character of his cosmology did not render it immune from demands for harmonisation with the biblical doctrine of creation. Disappointingly, this more explicit application of the Cartesian cosmogony to Genesis, like a number of Descartes' projected enterprises, never came about. In his exchange with Frans Burman two years later, Descartes explains that he 'abandoned the task because he preferred to leave it to theologians rather than provide the explanation himself'. He nonetheless maintained that he could provide 'an adequate explanation of the creation of the world based on his philosophical system, without departing from the description in Genesis'.[70]

What could Descartes have had in mind here? Had he intended a more general account of creation of the kind put forward by More, or did he mean to historicise his own hypothetical cosmology in the manner of Burnet? We shall never know. However, Descartes does provide us with hints as to the manner in which he was going to the tackle the problem of the Genesis narrative. It is not without significance that later in his conversation with Burman, he makes reference to Augustine's account of the creation, pointing out that in the writings of the Latin doctor, the days of creation are 'taken as intended purely for the sake of our way of conceiving of things'.[71] As we have seen, it was this traditional principle which informed the English theories of the earth and which it now seems likely Descartes had intended to avail himself of. It is quite possible that it was Augustine who provided the means by which Descartes thought his own account of the creation might be reconciled with that found in Genesis. Augustine had gone well beyond the principle of accommodation to harmonise the concepts of instantaneous creation and creation over time. Following the lead of a number of the Greek fathers, he had suggested that God created everything at once, but in the sense that all entities and events were present from the moment of creation potentially as seminal reasons (*rationes seminales*). Over time, these 'seeds' were to come to fruition of their own accord.[72] They accounted not only for the generation of the living things, but also for physical events. God did not need directly to interpose in the course of nature, for his will was effected through the coming to fruition of seeds implanted from the beginning of time.[73] For Augustine, nature itself was miraculous, and apparent miracles were unusual but not unnatural. Advocates of mechanism in the seventeenth and eighteenth centuries readily adopted this view to account for organic generation – the seeds of all living things, past, present, and future had been present from the beginning of time. Generation did not give rise to miraculous new productions, but was merely the augmentation of previously existing parts.[74] In his cosmology Descartes makes a similar case for the cosmos itself. There are no new productions in the cosmos, according to the Cartesian principle of the conservation of matter, nor new injections of motion. Instead the cosmos organises itself from 'seeds'. Descartes' use of the term is highly suggestive:

> So if we can devise some principles which are very simple and easy to know and by which we can demonstrate that the stars and the Earth, and indeed everything which we perceive in this visible world, could have sprung forth as if from certain seeds . . . we shall in that way explain their nature much better than if we were merely to describe them as they are now. . . . And because I think I have discovered some principles of this kind, I shall here briefly describe them.[75]

Descartes' 'seeds', of course, are not like those of the Stoics and Augustine – intrinsic to the natural order. Rather they are extrinsic laws of nature established and upheld by the Deity, and on the basis of which the development of the world unfolds naturally.[76]

The extent to which Descartes was indebted to Augustine in his plan to explain Genesis must remain a matter of speculation.[77] But what emerges from these disclosures to Boswell and Burman is that the curious combinations of natural philosophy and sacred history so characteristic of seventeenth-century English thought did not do great violence to the original intention of Descartes. Certainly it is worth bearing in mind that the English were the not the only ones to apply this natural philosophy to the text of scripture. Descartes' desire to leave to others this task of harmonisation was taken up by Cordemoy, Amerpoel, Le Grand, and Wittich. Cordemoy, perhaps overstating his case, claimed that Descartes' system 'does contain nothing dangerous; and that all he hath written of both, seems to have been taken out of the First Chapter of Genesis'.[78] Johan Amerpoel, in *Cartesius Mosaizans* (1677), places sections of the Genesis text side by side with extracts from the *Principia*, as if the latter were nothing but a commentary on the former. Christopher Wittich had argued similarly for the congruity of the Cartesian and Mosaic accounts of the creation in *Consensus veritatis in Scriptura divina . . . cum Veritate philosophica a Renato Cartesio detecta* (1659), while Antoine Le Grand introduced the three elements and Cartesian vortices into the Mosaic account of the creation.[79] These writers all assumed that such use of Cartesian philosophy was a natural, even obvious one.

Conclusion

I have argued in this paper that Descartes' hypothetical world and the historical worlds of the English cosmogonists were built upon common foundations, and that contemporary witnesses were correct to assume that Descartes was more than merely the symbolic leader of the seventeenth-century world-makers. But this is not to deny their differences. The single issue that remained between the Burnet-style of cosmogony and the Cartesian was to do with the role of history. Burnet had made clear the lines of the divide. Of the past mutations of the earth we have evidence, and it properly belongs in the province in history. About the origins of the universe we can but speculate.

For all this, *The Sacred Theory of the Earth* was deeply flawed. Burnet's error lay not in his attempt to historicise Descartes, but in the kind of evidence which he sought for his theory. The belief that certain privileged persons in the past had been granted revelations of truths concerning the origins of the earth, and that they had passed these truths on to others who had in due course had entered them into the annals of history, became in the latter half of the seventeenth century increasingly implausible. More, Burnet, Whiston and Woodward had each believed that knowledge of the narrow compass of human history had been extended in both directions by divine revelations. An account of the creation had been revealed to Adam and passed on the Moses; the future destruction and apotheosis of the world had been made known to the prophets. Now this 'revelatory time', which had made it possible for sacred history to provide a complete account of the world from beginning to end, was replaced by geological time, the scale of which was read not from biblical chronologies and prophecies, but from the world itself. The theorists were thus correct to claim that the world had a history, but mistaken in believing that evidence for that history could be found in ancient authorities. Rather, the earth itself embodied the physical evidence of its origins and development. This had already been recognised by contemporaries of the theorists, and indeed to an extent by John Woodward. Robert Hooke described fossils as 'the Metals, Urnes, or Monuments of Nature'.[80] In the following century Louis Buffon spoke similarly of the 'archives of the world', while Giraud consulted the 'annals of the physical world'.[81] The records which these investigators consulted consisted of the geological formations of the earth itself, not written human records.

Nonetheless, the differences between Descartes and his English imitators foreshadowed important controversies in both geomorphogeny and cosmology – in the eighteenth century, between catastrophists and uniformitarians, and in the twentieth century between advocates of the steady-state and the apocalyptic big-bang. Perhaps the most intriguing re-emergence of the old issues has come with the remarkable thesis of Immanuel Velikovsky, who in the 1950s posed the seventeenth century's cosmological questions anew.[82] As if quoting from Burnet's *Archaeologiae Philosophicae*, Velikovsky cites among the sources of his 'historical-cosmological story', 'the evidence of historical texts of many peoples around the globe', 'classical literature', and 'old astronomical inscriptions and charts'. Like Whiston, Velikovsky attributes to collisions of heavenly bodies catastrophic changes to the structure of the earth. He even accepts Whiston's case for a relatively recent change in the duration of the solar year, adding further historical evidence of his own.[83] In some small way, then, the issues of seventeenth-century cosmogony confront us still.[84]

Notes

1 Nicolson, Diary, 14 Jan 1706, qu. in J. Levine, *Dr. Woodward's Shield: History, Science, and Satire in Augustan England* (Ithaca, 1991), 323 n. 24.

2 Robert Jenkin, *The Reasonableness and Certainty of the Christian Religion*, 2nd edn. (London, 1700), x; John Keill, *An Examination of Dr. Burnet's Theory of the Earth*, 2nd edn. (London, 1734), 12, cf. 16; John Edwards, *Brief Remarks upon Mr Whiston's New Theory of the Earth* (London, 1697), 29, cf. Epistle Dedicatory, 37–9. See also John Sergeant, *Non Ultra: or, A letter to a Learned Cartesian* (London, 1698), 115–17.

3 For general accounts of these seventeenth-century theories of the earth, see Ernest Tuveson, 'Swift and the World Makers', *Journal of the History of Ideas* vol. 11 (1950), 54–74; Jacques Roger, 'The Cartesian Model and its role in eighteenth-century "Theory of the Earth" ', in T. Lennon, J. Nicholas, J. Davis, eds., *Problems of Cartesianism* (Kingston, 1982), 95–112; Gordon Davies, *The Earth in Decay: A History of British Geomorphology 1578–1878* (London, 1969), 1–94; Roy Porter, *The Making of Geology: Earth Science in Britain 1660–1815* (Cambridge, 1977), 1–90; Gabriel Gohau, *A History of Geology,* tr. A. and M. Carozzi (New Brunswick, 1991), 37–68.

4 *Principles* III art. 52. Cf. *Le Monde*, AT xi. 24–7, 50–3.

5 Descartes explains the spontaneous organisation of matter in *Le Monde*: 'For God has established these laws in such a marvellous way that even if we suppose he creates nothing beyond what I have mentioned, and set up no order of proportion within it . . . the laws of nature are sufficient to cause the parts of this chaos to disentangle themselves and arrange themselves in such good order that they will have the form of a quite perfect world. . . .' AT xi. 34.

6 *Principles*, IV art. 1; cf. *Discourse on Method* V, AT vi. 43ff.

7 The best account of Descartes' relation to More is Alan Gabbey, 'Philosophia Cartesiana Triumphata: Henry More (1646–1671)' in T. Lennon et al., eds., *Problems of Cartesianism*. Also see Marjorie Nicolson, 'The early stage of Cartesianism in England', *Studies in Philology* vol. 26 (1929), 356–74; Charles Webster, 'Henry More and Descartes: Some new sources', *British Journal for the History of Science* vol. 4 (1969), 359–77; A. Rupert Hall, *Henry More: Magic, Religion, and Experiment* (Oxford, 1990) 146–67; J. Saveson, 'Differing reactions to Descartes among the Cambridge Platonists', *Journal of the History of Ideas* vol. 21 (1960), 560–7; E.A. Burtt, *The Metaphysical Foundations of Modern Science* (Atlantic Highlands, 1952), 135–50; Amos Funkenstein, *Theology and the Scientific Imagination* (Princeton, 1986), 72–80. For a general account of Descartes' influence in England, see G.A.J. Rogers, 'Descartes and the English', in J.D. North and J.J. Roche, eds., *The Light of Nature* (Dordrecht, 1985) 281–301.

8 *The Conway Letters*, ed. M.H. Nicolson, rev. Sarah Hutton (Oxford, 1992), Letter 242 (p. 393); cf. Letters 127, 245, 216b (pp. 204, 397, 518); More, *The Immortality of the Soul* (London, 1659), Preface. On Descartes' introduction into the curriculum of the English universities also see John Gascoigne, *Cambridge in the Age of the Enlightenment* (Cambridge, 1989), 52–68; and Rogers, 'Descartes and the English', 300.

9 The plagiarisim thesis was a very common one in seventeenth-century England. Originally proposed by a number of the Church Fathers, the theory was that God had revealed to Adam all the secrets of nature. This knowledge passed through the hands of the patriarchs, Noah, Abraham, Zoroaster and Hermes

Trismegistus, thus coming eventually to Egypt. It was here that Moses become acquainted with this ancient philosophy. See, e.g., Theophilus Gale, *The Court of the Gentiles*, 4 vols. (Oxford, 1669–77), pt. II, passim; Nathaniel Culverwel, *An Elegant and Learned Discourse of the Light of Nature* (London, 1652), 67; John Keill, *Burnet's Theory of the Earth* (1734 edn.), 191; Ralph Cudworth, *The True Intellectual System of the Universe,* ed. John Harrison, 3 vols. (London, 1845) I. iv. 36 (vol. ii. 313); Robert Fludd, *Mosaicall Philosophy*, (London, 1659), 42; Lancelot Andrewes, *Apospasmatia Sacra* (London, 1657), 211f.; S. Gott, *The Divine History of the Genesis of the World* (London, 1670), 491; Robinson, *An Essay Towards a Natural History . . . to which is annexed A Vindication of the Philosophical and Theological Paraphrase of the Mosaick System of the Creation* (London, 1709), 8. Also see D.P. Walker, *The Ancient Theology* (Ithaca: Cornell University Press, 1972).

10 Henry More, *A Collection of Several Philosophical Writings* (London, 1662), xix. Others of the English Platonists endorsed More's view that the 'atomic' or 'mechanical' philosophy advocated by Descartes was but a revival of the science of Moses. See Ralph Cudworth, *A Treatise concerning Eternal and Immutable Morality* (London, 1731), 55, 301; Joseph Glanvill, *The Author's Defense of the Vanity of Dogmatising,* 89, in *Scepsis Scientifica* (London, 1665). Richard Bentley and Isaac Newton were similarly convinced that the philosophy of the moderns had been anticipated by the ancients. See Bentley, *The Works of Richard Bentley, D.D.*, ed. Alexander Dyce (London, 1838), iii. 374; Memoranda by Gregory, 5–7 May 1694, *The Correspondence of Isaac Newton,* (Cambridge, 1969), iii. 339; Royal Society, Gregory MS. 247; also see J.E. McGuire and P.M. Rattansi, 'Newton and the Pipes of Pan, *Notes and Records of the Royal Society of London* vol. 21 (1966), 108–43.

11 Henry More, *Defense of the Threefold Cabbala*, in *A Collection,* p. 79. It was a common complaint of Hermetic and Paracelsian writers that the four elements of Aristotle received no support in Genesis, which seems to refer to only three. See, e.g. Thomas Tymme, *A Dialogue Philosophicall* (London, 1612); Joseph Duchesne, *The Practise of Chymicall, and Hermeticall Physicke*, tr. Thomas Tymme (London, 1605), sigs. Civr-Dir.

12 Ibid, 80.

13 Ibid, 104. More emphasises that Cartesianism represents the 'physiological' elements in the Genesis account. For a complete restoration of the true natural philosophy of Moses, however, Platonism must be added. It was the fault of the subsequent philosophical tradition that the physical and spiritual elements of Mosaical philosophy were polarised into the materialism of the Greek atomists and the spiritualism of the Pythagoreans and Platonists. Both were essential elements, however, and More believed that Descartes represented a truly Christian atomism, which, when combined with Platonism, would lead to the restoration of the true natural philosophy. See *A Collection*, pp. vi, xii, xviii.

14 Henry More, *An Explanation of the Grand Mystery of Godliness* (London, 1660), 240, cf. 231–5. According to Gabriel Daniel another writer had done something similar: 'The Author of the treatise concerning *The Influence of the Stars*, describes the End of the World upon *Descartes* his Hypothesis'. *Voyage to the World of Cartesius* (London, 1692), 4. I have been unable to identify this work. In the passage above, incidentally, More was responding to an ancient objection against Christian eschatology, which he attributed to Caecilius Natalis, that the final conflagration of the world was against 'the Eternal Order constituted by the divine laws of nature' (7); Cf. Minucius Felix, *Octavius* XXXIV. As Minucius had used Stoic philosophy to defend the reasonableness of Christian belief, now More adapted Descartes to the same purpose. For criticism of More's use of Cartesian principles see Samuel Parker, *A Free and Impartial*

Censure of the Platonick Philosophy, 2nd edn. (Oxford, 1667), 84–8, 109f.; *Disputationes de Deo et Providentia Divina* (London, 1678), 294f., 324.

15 Title page of the second English edition (1691). The English editions were, strictly, not merely translations but variations on a theme, 'a new Composition on the same ground', as Burnet referred to it in his Preface to the English edition. On the differences between the two versions, see M.C. Jacob and W.A. Lockwood, 'Political Millenarianism and Burnet's *Sacred Theory*', *Science Studies* vol. 2 (1972) 265–79; also Scott Mandelbrote, 'Isaac Newton and Thomas Burnet: Biblical criticism and the crisis of late seventeenth-century England', in R. Popkin and J. Force, eds., *The Books of Nature and Scripture* (Dordrecht, 1994) 149–78 (170, n. 25).

16 Burnet's own view of his indebtedness to Descartes was expressed thus: 'An eminent Philosopher of the Age, *Monsieur des Cartes*, hath made use of the like *Hypothesis* to explain the irregular form of the present Earth; though he never dream'd of the Deluge, nor thought that the first Orb build over the Abysse, to have been any more than a transient crust, and not a real habitable world. . . .' Cf. *Telluris Theoria Sacra*, C. 7 & lib. 2, c. 4. The more perspicacious of Burnet's readers recognised the extent of his reliance of Decartes, and generally held it against him. See, e.g., Keill, *Burnet's Theory of the Earth* (1734 edn.), 309f.; Erasmus Warren, *A Defense of the Discourse concerning the Earth Before the Flood* (London, 1691), 16f.; M. Christina Wagner, *Animadversiones in T. Burnetti Telluris Theoriam Sacram* (Leipzig, 1683), 5.

17 *The Sacred Theory of the Earth* I, v-vi (London, 1965), 54–68. Subsequent page references to Burnet's *Sacred Theory* come from this reprint of the 2nd edn. of 1691.

18 Ibid., III, vi (264–70). The first possibility was dismissed by Burnet, in part, because he wished to salvage something for the creation of a new earth. The second possibility was one which attracted a number of supporters during the 1690s. Thomas Robinson, e.g., affirmed the hypothesis. *New Observations of the Natural History of this World* (London, 1696), 177f.; Naturalist John Ray, like Burnet, thought it unlikely. *Three Physico-Theological Discourses*, 2nd edn. (London, 1693), 316.

19 Ibid, III, vii (276).

20 Steno's most famous work, *Prodromus* (1667), appeared in English translation in 1671 – *The Prodromus to a Dissertation concerning Solids Naturally Contained within Solids*, tr. Henry Oldenburg (London, 1671). On Steno's influence see V.A. Eyles, 'The influence of Nicolaus Steno on the development of geological science in Britain', in G. Scherz, ed., *Nicolaus Steno and his Indice* (Copenhagen, 1958), 167–88.

21 Porter, *Making of Geology*, 30.

22 William Whiston, *A New Theory of the Earth* (London, 1696), 69–71.

23 Ibid, 258f.

24 'If therefore the upper Regions of a Chaos, whose quantity of Liquid is very small in comparison of its solid Corpuscles, do subside into a Fluid of greater specifick Gravity than its own Columns taken together are; an Orb of earth will be compos'd on the Surface of the Fluid, and its different Columns being made up of Bodies of very different Natures and specifick Gravities . . . that Orb will sink into the Fluid in different degrees, and thereby render its Surface unequal, or distinguished into Mountains, Plains, and Vallies.' Ibid, 61f.

25 William Whiston, *Astronomical Principles of Religion*, (London, 1717), 156. On the late seventeenth- and early eighteenth-century tendency to identify various celestial bodies with heaven or hell, see Philip C. Almond, *Heaven and Hell in Enlightenment England* (Cambridge, 1995), 125–30.

26 Burnet thus wrote in high spirits to his friend Robert Southwell that the last

two books of the English edition of the *Sacred Theory* 'had passt the Pikes at Lambeth', an indication that the work had been authorised by the Archbishop of Canterbury. See Levine, *Dr. Woodward's Shield*, 25.

27 Newton to Burnet, January 1680/1, *Correspondence of Isaac Newton*, ii. 331. For an account of the complex relation between Newton and Burnet see Mandelbrote, 'Isaac Newton and Thomas Burnet'. William Temple also approved of the work, according to its author. See *The Life of Thomas Burnet, D.D.* 14, in *Doctrina Antiqua de rerum Originibus*, tr. Mr Mead and Mr Foxton (London, 1736).

28 Whiston, *Memoirs*, 3 vols. (London, 1749) i. 43.

29 For standard treatments see: Andrewes, *Apospasmatia Sacra*, 4; Edward Stillingfleet, *Origines Sacrae*, 7th edn., (Cambridge, 1702), III, ii (pp. 283–316); Melchior Leydecker, *Republica Hebraeorum* (Amsterdam, 1704), 23–30. Cf. Burnet, *Sacred Theory* I, 1, 3, 12 (pp. 24, 33–53, 121f).

30 The Stoic view had its attractions, nonetheless, and a number of Christian thinkers had been drawn to it. Minucius Felix relied upon it to refute Aristotle, and Origen seems to have believed in a succession of worlds. In the seventeenth century More, Jean Baptista van Helmont, Burnet, and others also subscribed to the doctrine of a temporal succession of worlds. See, e.g., More, *Democritus Platonissans* (Cambridge, 1646), stanzas 70–6; van Helmont, *The Paradoxal Discourses . . . concerning the Macrocosm and Microcosm* (London, 1685); Burnet, *Sacred Theory* IV, Preface (16), *De Originibus Rerum*; 82–5. Cf. Anonymous, *Seder Olam: or, The Order, Series, or Succession of all the Ages, Periods, and Times of the Whole World* (London, 1694), 22, 31. Burnet actually pointed out the similarity between scriptural and Stoic doctrines on this question. *De Originibus Rerum,* 213, 82–5, in *Doctrina Antiqua.*

31 For the Medieval treatment of Aristotle on the eternity of the world, see: Boethius of Dacia, *On the Supreme Good, On the Eternity of the World, On Dreams*, tr. John Wippel (Toronto, 1987); *St. Thomas Aquinas, Siger of Brabant, St. Bonaventure: On the Eternity of the World*, tr. C. Vollert, L.H. Kendziersky, P.M. Byrne (Milwaukee, 1964); John Wippel, 'Did Aquinas defend the possibility of an eternally created world?', *Journal of History of Philosophy* vol. 19 (1981), 21–37.

32 Edward Stillingfleet, *Originis Sacrae,* incomplete edition, appended to the 7th edn. (Cambridge, 1702), 122; John Keill, *An Examination of the Reflections on the Theory of the Earth together with a Defense of the Remarks on Mr Whiston's New Theory* (Oxford, 1699), 11. Cf. Samuel Parker, *Disputationes de Deo* (Londini, 1678), 294f.; Edward Howard, *Remarks on the New Philosophy of Descartes* (London, 1700), 288; John Sergeant, *Solid Philosophy Asserted* (London, 1697), Sig. A4r.

33 William Whiston, *A Vindication of the New Theory of the Earth* (London, 1698), 30.

34 Howard, *Remarks on Descartes,* 207. Howard preferred Aristotle to Descartes (288).

35 John Edwards, *Whiston's New Theory,* Epistle Dedicatory, 23–6. Edwards considered the Copernican hypothesis and Cartesian philosophy to be mere fads. On the connection between final causes and cosmology, see John Witty, *An Essay towards a Vindication of the Vulgar Exposition of the Mosaic History of the World* 2 vols. (London, 1705) i. 105, 108f. Also see Robert Boyle, *A Disquisition about the Final Causes of Natural Things* (London, 1688), Preface, 32f., for a comparison of the Cartesian and Epicurean denials of final causes.

36 John Edwards, *A Demonstration of the Existence and Providence of God* (London, 1696), 6, 42, 13, and passim.

37 A litmus for such disputes was the status of mountains. In Burnet's *Sacred Theory*, mountains are ugly pockmarks on the surface of the earth, whose only use is to serve as a reminder of the fallen condition of the human race. Numerous writers who came after him, however, were concerned to stress the utility of

mountains, and thus indirectly point to God's providence in providing them. See, e.g., John Ray, *Miscellaneous Discourses Concerning the Dissolution and Changes of the World* (London, 1692), 165; also Marjorie Nicolson, *Mountain Gloom, Mountain Glory* (New York: Norton, 1963).

38 Nicolson to Lhwyd, 31 Jan. 1698, in Nicolson, *Letters*, i. 103–5. Levine, *Dr. Woodward's Shield*, 38.

39 Edwards, *Whiston's New Theory*, 7, 23–6; cf. *Existence and Providence of God*, 11–18, 168. Keill, *An Examination of the Reflections*, 11. Also see Witty, *Mosaic History of the World,* I, Preface, 59f., II, 1–5; Erasmus Warren, *Geologia: or, A Discourse concerning the Earth before the Deluge* (London, 1690), 58f.

40 John Arbuthnot, *An Examination of Dr. Woodward's Account of the Deluge* (London, 1697), 29.

41 Thomas Robinson, *An Essay*, Preface.

42 Robert St Clair, *The Abyssinian Philosophy Confuted: or Telluris Theoria neither Sacred not Agreeable to Reason* (London, 1697), 89, cited in Tuveson, 'Swift and the World Makers', 65.

43 Howard, *Remarks on Descartes,* Preface.

44 Edwards, *Whiston's New Theory*, 39. Cf. Robert St Clair, *The Abyssinian Philosophy Confuted,* To the Reader; Gott, *Divine History*, 5. Erasmus Warren actually thought that the hypothetical nature of Descartes's original proposal gave it the advantage over later theorists who had claimed 'more than a moral certitude.' *A Defense*, 22f. Cf. John Edwards, *A Discourse concerning the Books of the Old and New Testament* 3 vols. (London, 1695), iii. 329.

45 By way of contrast, earlier in the century Joseph Glanvill had lauded Descartes as a Baconian: 'Indeed the impatient mind of Man, as my Lord *Bacon* observes, is too apt to fly to general conclusions; and more averse to the way of *experiment* and *induction*, which he thought the only method for the establishing of a solid and grounded Theory: In which there is none has more highly succeeded than the Philosopher *Des-Cartes. . . .*' *The Author's Defense of the Vanity of Dogmatising*, 72, in *Scepsis Scientifica.*

46 Keill, *An Examination of Dr. Burnet's Theory of the Earth* (Oxford, 1698), 30.

47 Arbuthnot, *An Examination*, 7f.

48 Keill, *Burnet's Theory of the Earth* (1734 edn.), 14, 39f., 10, 323, 16. Ironically this last criticism was to become More's greatest fear with respect to Cartesian mechanism. See *Epistola H Mori as V.C.* (London, 1669), *Divine Dialogues*, 2 vols. (London, 1669), i. 'To the Reader'. Also see Gabbey, 'Philosophia Cartesiana Triumphata', 236–43.

49 Jacques Roger, 'The Cartesian Model'. So too, Francois Duchesneau, 'the attempt to reconcile his [Descartes'] views with the text of the Bible will appear as a mere replastering', 'The Role of Hypotheses in Descartes's and Buffon's Theories of the Earth', 114, also in T. Lennon et al., eds., *Problems of Cartesianism*, 113–25.

50 AT xi. 48. This premiss is actually suggestive of an historical world, for the notion of miracle implies a temporal sequence of ordered events which are interrupted. The phrase 'course of nature' likewise seems to imply a temporal sequence.

51 More, *An Explanation*, 237. But cf. 240, where he retreats from this: 'I say therefore, that the earth will thus at the long run be burnt, *either according to the course of Nature . . . or else by a more special or solemn appointment of Providence*'. More's dilemma arose out of the fact that the timing of the end of the world was supposed to be known to no-one, yet if brought about by natural causes it would have been in principle predictable.

52 Burnet, *Sacred Theory*, III, viii (281).

53 Whiston, *New Theory*, 359. Other advocates of the mechanical philosophy held

similar views. Plant physiologist Nehemiah Grew wrote that 'God having made, and put into Perfect order, a World of Instruments or Second Causes: it seems not becoming his Divine Wisdom and Majesty; to do any thing without the Mediation and use of these Causes'. *Cosmologia Sacra* (London, 1701). Thomas Robinson agreed that 'these Laws and Rules which the Divine Wisdom gave to the Second Causes to work by, he never interrupts or varies from; but upon great and extraordinary occasions'. *New Observations*, 12. On this tendency for seventeenth-century natural scientists to give naturalistic explanations of miracles, see Peter Harrison, 'Newtonian science, miracles, and the laws of nature', *Journal of the History of Ideas* vol. 56 (1995), 531–53.

54 Roger, significantly, postpones this development until the 1750s: 'Not before Maupertuis, that is, in the 1750s, was the argument from design transferred from purposeful structures to purposeful laws.' 'The Cartesian Model', 99. This may be true with regard to biological structures. Indeed it was true of them up until the time of Darwin. This accounts the popularity of such mechanical accounts of generation as preformation. However, things are less clear in the case of the physical universe.

55 Part of the case of theorists was typically a refutation of Aristotle. Thus, for example, Burnet: Aristotle was 'a *bad* Astronomer, a *worse* Divine, and the *worst Philosopher*'. *De Origibus Rerum,* 250. Critics of the theorists help make this point. For Edward Howard, Aristotle was to be preferred to Descartes. *Remarks on Descartes*, 288.

56 More, *A Defense of the Three-fold Cabbala*, 80. Cf. Anonymous, *Two Remarkable Paradoxes* (London, 1681), 1.

57 When Descartes announces in the *Principles* that 'In order to better explain natural things, I may even trace their causes here to a stage earlier than any I think they ever really passed through', he clearly implies that the earliest stages of his hypothetical cosmology could be compressed into an instant of time. *Principia* III. art. 45. Cf. Roger: 'The development of time through which the succession of events developed itself in Descartes's cosmogony was a theoretical one, able to be actually reduced to the very instant of the creation.' 'The Cartesian Model', 105.

58 Burnet to Newton, *Correspondence of Isaac Newton*, ii. 323.

59 Roger, 'The Cartesian Model', 103.

60 For the impact of this change on seventeenth-century natural philosophy, see Peter Harrison, *The Bible, Protestantism, and the Rise of Natural Science* (Cambridge, 1998), esp. 107–20.

61 These were necessitated partly by the fact that Genesis itself presents two distinct accounts of the order of creation (Genesis 1.1–2.3, and 2.4–2.25) – the so-called 'Yahwist' and 'Priestly' sources. Another influential source was the book of Ecclesiasticus, which, in the Vulgate edition, speaks of simultaneous creation: 'Qui vivit in aeternum creavit omnia simul' (18.1). The crucial 'simul' (simultaneously) disappears in the English of the Authorised Version.

62 Augustine, *De Genesi ad litteram* V. 4. 9–11; *Confessions* XII. xvii; Cf. Aquinas, *Summa theologiae*, 1a 2ae. 98, 3. Augustine also warned against the use of the authority of scripture in disputes about natural philosophy, a point noted by Burnet, *Sacred Theory*, Preface (16). For Augustine's relevance to seventeenth-century biblical criticism see Scott Mandelbrote, 'Isaac Newton and Thomas Burnet', 150–3.

63 Edward Grant, *Planets, Stars, and Orbs: The Medieval Cosmos, 1200–1687* (Cambridge, 1995), 83.

64 Thus, Philo, *De opificio mundi* 3.13f. Also see Funkenstein, *Theology and the Scientific Imagination*, 324f.

65 *Conway Letters*, Letter 42 (p. 82). More also believed that revealed tradition

could not contradict natural science: 'Since Revelation must be handed down by tradition, and Tradition being but humane Testimony, and infinitely more lubricious and fallible than either ξοιναὶ ἔρννοισι or *natural science*; How will it be possible for any but Sots or Fools to believe *Tradition* against *solid Science* or a *Common Notion*.' *A Brief Discourse of the True Grounds of the Certainty of Faith in Points of Religion* in *Theological Works* (London, 1708), 767.

66 Burnet, *A Re-Survey of the Mosaic System of the Creation*, tr. Foxton (London, 1728), 23f, 4.

67 Paraphrased from *Archaeologiae philosophicae* 1.2, by Edwards, *Discourse concerning the Old and New Testament*, ii. 35.

68 Whiston, *New Theory* 380; 'Of the Mosaic Creation', 19, 82, in *New Theory*. Descartes makes a similar point in his *Second Set of Replies*: 'as everyone knows there are two quite distinct ways of speaking about God. The first is appropriate for ordinary understanding and does contain some truth, albeit truth which is relative to human beings; and it is this way of speaking that is generally employed in Holy Scripture. The second way of speaking comes closer to expressing the naked truth – truth which is not relative to human beings; it is this way of speaking that every ought to use when philosophizing.' AT vii.142.

69 Descartes to William Boswell, 1646, AT iv. 698, qu. in Popkin, 'The Third Force', 56. (*Principia* was published in 1644; Fr. tr. 1646).

70 'Conversation with Burman', 16 April 1648, AT v. 168.

71 Ibid. Galileo, too, was also familiar with the patristic tradition of exegesis of Genesis, and had invoked the authority of Augustine in his own defense, significantly to no avail. Galileo's censure is thus evidence of a hardening of attitude on the part of ecclesiastical authorities. What emerged from the Galileo affair was that the issue was less to do with biblical interpretation per se, and everything to do with authority of the Church and ecclesiastical politics: certainly the insistence on a literal reading of scripture was not of central importance. Galileo, *Letter to the Grand Duchess Christina concerning the use of Biblical Quotations in Matters of Science* (1615), in *Discoveries and Opinions of Galileo*, ed. Stillman Drake (New York, 1957), 175–216. Also See John Brooke, *Science and Religion: Some Historical Perspectives* (Cambridge, 1991), 77–81.

72 Étienne Gilson, *The Christian Philosophy of Saint Augustine* (London, 1961), 197–209; Michael McKough, *The Meaning of the Rationes Seminales in St Augustine* (Washington, 1926). The idea of seminal principles was still current in Descartes' time. Thus Jean d'Espagnet: 'The specifical forms from the first day of Creation, were imprinted in the first individual and particular persons, by the character of the Idaeal copie, and . . . by the way of generation traduced to posterity. . . .' '. . . so all individuals before they come to light, are in the World in their matter and potentiality, and will in their time and order come forth and break into act. . . .' *Enchiridion physicae restitutae* (London, 1651), 109, 122 (First Latin edn., Paris, 1623).

73 According to Robert Grant, Augustine argued that miracles were 'due to the *semina seminum* implanted in the world at creation. The "seeds" ultimately produce the miracle in nature.' *Miracle and Natural Law in Graeco-Roman and Early Christian Thought* (Amsterdam: North Holland, 1952), 217. This assertion of Augustine's naturalism has been challenged (though unsuccessfully in my view) by John Hardon, 'The concept of miracle from St. Augustine to modern apologetics', *Theological Studies* vol. 15 (1954), 229–57.

74 See, e.g., Malebranche, *Father Malebranche, His Treatise concerning the Search after Truth,* 2nd edn., tr. T. Taylor (London, 1700), 54; J. Swammerdam, *Historia insectorum generalis* (Utrecht, 1669), pt II, 29f.; Whiston, *New Theory*, 224; Bentley, *Works,* iii. 83; Nicasius le Fabure, *A Compleat Body of Chemistry* (London, 1664), 14; Ray, *Three Physico-Theological Discourses,* 46–50, 60f.; J.B. van Helmont,

A Cabbalistic Dialogue (London, 1682), 135, 153; George Cheyne, *Philosophical Principles of Religion: Natural and Revealed,* 2nd edn., (London, 1714), 168; Derham, *Physico-Theology*, 246. Richard Bentley, *Works* iii. 83; Leibniz, *Leibniz-Clarke Correspondence*, ed. H.G. Alexander, (Manchester, 1976), p. 93; Noël Antoine Pluche, *Spectacle de la Nature,* 5th edn., 7 vols., (London, 1770), i. 11f., 250, 275. On theories of embryological pre-existence, see Jacques Roger, *Les Sciences de la Vie dans la Pensée Francaise du XVIII^e^ Siècle*, 2nd edn., (Paris: Armand Colin, 1971), ch. 3; Peter Bowler, 'Preformation and pre-existence in the seventeenth century', *Journal of the History of Biology* vol. 4 (1971) 221–44; Edward Ruestow, 'Piety and the defense of natural order: Swammerdam on generation', in Margaret Osler and Paul Farber, eds., *Religion, Science, and Worldview* (Cambridge, 1985).

75 *Principles,* III art. 46. Also see Whiston's discussion of the creation of the seeds of living things: *New Theory*, 223f.

76 *Discourse on the Method* V, AT vi. 44f. Cf. letters to Mersenne, 15 April 1630, AT i. 145; 27 May 1630, AT i.152.

77 It is significant that Mesland had pointed out to Descartes his affinity with some of Augustine's ideas. Descartes to Mesland, 2 May 1644, AT iv. 113. In a recent paper Hans Aarslef also gives some circumstantial evidence of possible Augustinian influence on Descartes' reading of Genesis. See 'Descartes and Augustine on Genesis, Language, and the Angels', in Marcelo Dascal and Elhanan Yakira, eds., *Leibniz and Adam* (Tel Aviv, 1993), 169–95.

78 Cordemoy, *A Discourse written to a Learned Frier* (London, 1670).

79 Antoine Le Grand, *An Entire Body of Philosophy According to the Principles of the Famous Renate Des Cartes* (London, 1694), 56–8.

80 'Lectures and Discourses of Earthquakes and Subteranean Eruptions', 335, in *Posthumous Works of Robert Hooke* (London, 1705).

81 Both quoted in Gohau, *A History of Geology*, 66.

82 Velikovsky's thesis, in a nutshell is: '(1) that there were physical upheavals of a global nature in historical times; (2) that these catastrophes were caused by extraterrestrial agents; and (3) that these agents can be identified.' Immanuel Velikovsky, *Worlds in Collision* (London, 1972), 9.

83 Ibid, 9, 316.

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Part II

Method, optics, and the role of experiment

9 Neo-Aristotle and method

Between Zabarella and Descartes

Timothy J. Reiss

The past half century has seen much debate among historians of ideas, philosophy and science about the origins of the modern idea of science. Since John Herman Randall Jr's now almost too famous essay, 'The development of scientific method in the School of Padua', scholars have wrestled over whether sixteenth-century debates on 'method' and the later growth of modern western science were continuous or discontinuous, and over what might be the nature of either. Partly due to the essay itself and partly due, too, to the role traditionally given Galileo as the originator of modern science, the debate has always taken him as the proper final arbiter and *terminus ad quem* for all aspects of the argument. Since he was trained and then taught at Padua, and always worked in Italy, the role is in some sense a given. I do not contest the validity of this aspect of the arguments.[1] I do, however, want to add what seems to be evidence of complex continuity from another quarter, not so much new as newly construed. This may allow us not so much to settle the issue of continuity or discontinuity, which depends mostly on how one defines the two, as to see better how cultural creation operates, how cultures get from one way of understanding and analyzing their human condition to other ways, how some earlier forms give way, disappear or remain 'unused' ('residual'), how others emerge into new light, are reconfigured to new ends and make new uses, and how yet others get set into new relationships.

This essay proposes that evidence in Descartes' writing lets us trace a path from Jacopo Zabarella's (1533–89) rethinking of Aristotle to Descartes' 'own' *méthode*. I do not argue connection or direct influence. Such claims are mostly pointless and usually fruitless endeavours: first because 'personal' connection, if it exists (as it does not here), is likely to be uninterestingly trivial, and second because possible lines of influence are always overdetermined and anyway manifold. But I do want to give a sense (1) of how Descartes reworked neo-scholastic thinking about method, and (2) of the extent to which, in doing so, he summed up sixteenth-century debate on the subject. With much of this he would have been acquainted from his three years of training in philosophy at the Jesuit college of La Flèche, even if his own interest in questions of knowledge and discovery had not inclined him to pay attention to its conclusions. As we get through (2), we will, I think, come to understand (1), its considerable importance in Descartes' actual working out of what he called *méthode*, and perhaps, too, something of his hopes as to what *méthode* would let him and others do. Together, these allow a new evaluation of how Descartes *did* draw *méthode* from earlier ways of conceiving the possibilities of discovery in natural philosophy, and how he used them to specify the nature of 'mathematical' method. While arguing this, this essay nonetheless remains, I think, rather a preliminary report than a definitive case.[2]

I start with proposals made by the Cartesian Nicolas-Joseph Poisson (1637–1710) about Descartes' having used neo-Aristotelian analysis and synthesis (resolutive/compositive method), the lack of any Cartesian 'circle', and Descartes' having followed the Jesuit Francisco Toleto (1532–96) in the matter of method (his writings were among those prescribed in the Society's colleges), and with Poisson's unattributed use, in all this, of a paraphrase of a major passage from Zabarella's *De regressu* (1578). Here, if we are to grasp Poisson's argument and its basis in Descartes' own writing, we need to look at the debates which Poisson had in mind and at modern-day exegeses of them. I combine these in the hope of mutual clarification. The issues in the debate then return to Descartes, who was certainly aware of them as he developed the *Regulae* between 1618/19 and 1628, discussed the *Méthode* in 1637–38, and took on Marin Mersenne's (1588–1648) Second Objections to the *Meditationes* in 1641 – if these were not actually the work of Jean-Baptiste Morin (1583–1656), to whose earlier epistolary objections to the *Discours* they seem clearly related, as Daniel Garber argues.[3] Here, I pay especial attention to Descartes' controversial remarks on a priori, a posteriori, synthesis and analysis, urging that they show how he 'turned' these earlier points of reference to something very like *méthode* as he depicted it in the sixth part of the *Discours*. This also shows that if Garber is right in arguing that by the time of the *Meditationes* Descartes' had changed his 'method', that did not stop him using its older form as explanatory means.[4] The after-the-fact explanation gives insight into the 'sources' of *méthode* itself and into how older concepts get put in unfamiliar relations to 'new' purpose. But the explanation was not only 'after-the-fact', since it seems first to have been proposed, albeit tentatively, in the *Regulae*.

The fact is that from his earliest writings, Descartes had shown a combative awareness of being involved in vehemently debated issues concerning the nature of knowledge and methods of understanding. His first 'published' work, the dedication to his uncle of the broadsheet of his 1616 law theses, already rejected humanistic learning in favour of the law, in terms not so very different from those he would famously use of mathematics in the *Discours de la méthode* twenty years later.[5] If he held back *Le Monde* in 1633, supposedly for fear of emulating Galileo's case but actually for several complex reasons, in 1641 he published the first edition of the *Meditationes* with *Objections* and *Replies*, deliberately seeking controversy.[6] He went further in 1642 by including in the second edition a new set of Objections and Replies and a long, acid *Lettre à Dinet*, rejecting what he called these pettifogging Objections of the Jesuit Pierre Bourdin (1595–1653). This letter, in which he also defended his disciple Henricus Regius (1598–1679), censured by the University of Utrecht earlier in 1642 at the instigation of its rector Gisbertus Voetius (1589–1676) for teaching 'Cartesian' philosophy, spurred an acrimonious dispute over the next five or so years. This did not, however, stop Descartes from planning (as he said in several letters) to write his *Principia philosophiae* as a school text, whose format would be a question and answer refutation of current scholastic philosophy – especially, of course, in those domains of particular interest to him. It would be deeply surprising if it was mere coincidence that the title of his first real published work, *Discours de la méthode*, referred to the long, important and familiar debates on method that had preceded it.

A generation later, however widely known Descartes' thinking had by then become, it was still far from accepted in the colleges and universities. One might, therefore, be tempted to take Poisson's defence, placing Descartes in a neo-Aristotelian tradition, with a pinch of salt. A disciple and apologist wanting to support his protagonist with the weight of traditional authority would surely be ready to give himself some latitude of assertion? Allowing for this, his claim could hope to work only if those to be persuaded found it credible – especially at a time when Cartesianism was under attack for sapping that very authority.[7] Hence we may suppose that as late as 1670, the date of Poisson's *Commentaires ou remarques sur la méthode de René Descartes*, contemporaries could agree that, however new the philosophy defended, it was still in a way embedded in the older debates and shared much of the same ground. In 1671, Jacques Rohault (1618–72) did not hesitate to claim in his *Traité de physique* that Descartes had simply set Aristotle's science on a firmer foundation.[8] Three years on, René Le Bossu (1631–80) wrote an entire treatise on the matter, *Parallèle des principes de la physique d'Aristote & de celle de René Des Cartes* (Paris, 1674). That Cartesianism thrived despite the theological and political forces deployed against it in France implies that the conflict mattered less than Descartes' supporters thought or, more likely, that their traditionalist arguments were not at all unbelievable.[9] I will go on to make the stronger claim that they drew these arguments from Descartes' own writing.

Descartes, wrote Poisson, familiarly employed '*l'Analytique & Synthetique*', analysis and synthesis, the first of 'which teaches us to divide; and the other [of] which teaches us to reassemble and to compose'. The mind perceiving effects, said Poisson, is like a chemist's fire, 'the grand *resolutive*' (his italics), and Descartes 'knew better than any' how to use these methods.[10] He came back to the matter when writing on the question of the logical circle (to be discussed later), denying, in much the same terms as Zabarella, Galileo and others, as well as Descartes himself, that a 'circle' was at issue. The first analysis (resolution) presented an indistinct and confused hypothesis regarding cause. Only reconsidered, clarified and generalised, could a clear and distinct explanation of cause be provided. Poisson found his terms of denial in the Jesuit thinker, Toleto, with whose work Descartes was familiar and for whom he recorded his admiration.[11] At any rate, the *Ratio studiorum* stipulated Toleto's work for use in the philosophy cursus of the Jesuit colleges. Poisson remarked:

> Here M. Descartes simply followed Toleto's view, which is also that of St. Thomas. Here are his words. *Although*, says [Toleto], *we know the existence of an effect before that of a cause, this knowledge is only imperfect and particular: but when we use it for a demonstration, then we have a clear and universal knowledge of it. Aristotle also teaches this* (Post. Anal., Bk. 1, ch. 24) *when he says that although we know that the particular triangle has three angles, we yet require some principle to make this notion more general. . . . And the knowledge we have of the effect has been means to reach that of the cause. By this rough knowledge we have of the cause with some other reasons that we have from elsewhere, we finally know this cause clearly and perfectly, so that using the notions we [now] have of it, we return towards the effect which we then know more perfectly, and in a quite other way from how we know it before we knew its cause by its means.* So we see [Poisson concludes] how cause and effect interact mutually to become known [*s'entraident à se faire connoistre*], and how this perfect correspondence existing among all things so clearly proves their existence.[12]

Poisson was echoing neo-Aristotelian debates from the end of the previous century. I assume he was quoting from Toleto's 1572 *Commentaria in universam Aristotelis logica*, but have not traced an exact source or checked accuracy. For my purpose here, neither matters. Poisson was, certainly accurately repeating the *kind* of argument Toleto and others had made, even if we cannot find this particular form of words. Indeed, as I have already suggested, Poisson's final gloss paraphrased an important argument in Zabarella's *De regressu* (1578). We shall see that the argument which Poisson ascribed to Toleto accurately described conclusions about the relation of resolution, composition and *regressus* as Zabarella advanced them. It also neatly linked physical and mathematical (Aristotelian and Euclidian) methodical practices that had been often contentiously kept apart. Poisson doubtless named Toleto rather than Zabarella because the cardinal's name would carry more weight with traditionalists, some of whom might recall the major role he had played in getting Clement VIII to lift Henri IV's excommunication in 1595. That the argument put forward under his name described aspects of Descartes' work and arguments is the main aim of this essay. But before embarking on that argument, I need to detail just what were the debates to which Poisson was referring here through Toleto.

I began by mentioning Randall's essay on what he called 'the School of Padua'. There, it was argued that debates about method, drawn from Aristotle, Euclid, Galen and Averroist commentaries on Aristotle, peaked at the University of Padua late in the sixteenth century, being drawn together into a modern scientific method to which Galileo only needed to add mathematics. Ernst Cassirer, who had also once proposed that Zabarella's method was basically that of Galileo without the mathematics, later disputed Randall's view on the grounds that Galileo derived his distinction between 'analysis' and 'synthesis' not in the neo-Aristotelians but in Euclid, giving to 'the Greek classical method of "problematical analysis" a new breadth and a new depth' by applying it to physical thought, an area where it had not been applied before. Only Galileo's words, said Cassirer, came from the Aristotelians: 'resolutive' for Euclid's 'analytic', 'compositive' for 'synthetic'.[13] Neal Gilbert developed this denial in a short essay on the disagreement, printed after he had published a book on the sixteenth-century debates themselves.[14] He surmised that Galileo could have taken his terminology directly from the Greek mathematical works by then available to him. He also urged that, whereas Galileo condemned the syllogism as useless for discovery, Zabarella thought it the single instrument of true science. But just what was really at issue here?

Part of the problem, William Edwards objects, was that too sharp a division between the 'medico-philosophical' (Aristotelian and Galenic) and the mathematical traditions was being made. In fact, the issue had been joined from the earliest commentators on Galen's *Ars medica* (or *Ars parva*) as to whether the 'analysis' of its first chapter or 'prologue' was the same as 'the analysis of the geometers'. Further, the 'regressive demonstration' as developed by 'the Averroist-Aristotelian commentators [thirteenth-sixteenth centuries] on the *Ars medica* and the *Posterior Analytics*', a tool by which demonstration *quia* or *hoti* drawing cause from effect was 'turned about' (*regressus*) to a demonstration *propter quid* or *dioti* to show the effect from its cause, was itself an effort to endow natural philosophy 'with a method that would be equivalent in degree of certitude (or as nearly so as possible) to the kind of "absolute" demonstration Averroes saw in mathematics'.[15]

In the *Ars medica*, what Galen actually defined were three 'ordered modes of instruction' (*didaskaliai taxeos echomenai* or, as usually given, *doctrinae ordinatae*): analysis, by resolution of the idea of an end, synthesis, composition of what was found by resolution, and 'dissolution of a definition'. Edwards suggests that early commentators simply tried to tie these to other known methods, 'the *analysis* and *synthesis* of the Greek mathematicians and the two kinds of demonstration', *quia* and *propter quid*, of the *Posterior Analytics*. The earliest, 'Ali ibn Ridwan (d. 1061), directly equated Galen's *analysis* with that of the geometers and with Aristotelian *quia*. In doing so, he proposed that a method that Galen had offered as a means for organising an entire discipline (*doctrina*) was *also* a way to solve particular problems. He was understood in this way by later commentators from Pietro d'Abano (1250–c. 1316) to Nicolò Leoniceno (1428–1524). It was then logical to equate Galen's synthesis with that of the geometers and with the Aristotelian demonstration *propter quid*, leaving *definition* out in the cold, since neither of the others had such a third method. There it remained until the sixteenth century.

One difficulty in the analysis equation was that geometers and physicians asked different sorts of questions. The former typically assumed what they wished to demonstrate and worked back through the assumption's consequences to something known to be true or false (analysis). They could then work from the axiom to its now proven consequences (synthesis). Physicians, however, like natural philosophers, worked from known effects to unknown causes – which might remain unknown: what mattered was that they could be controlled in order to *change* the effect. 'Ali seems to have been thinking not of diagnosis but of constructing the art of medicine; analysis would allow the physician to come not to known causes of illness but to more basic 'known' arts that would enable him to make decisions about cures, diet, regimen and medicines.[16] Only in Pietro d'Abano did analysis seem to be a method for finding causes of effects rather than the principles of an art. He knew both 'Ali and, more importantly, the writings of Averroes (1126–98) on logic and method.

Now, Averroes distinguished the *demonstratio simpliciter* ('absolute' demonstration) possible in mathematics from the sort of demonstrations possible in natural philosophy – or medicine. The first, he said, was at once knowledge of the fact and of the reasoned fact. Once the mathematician had reasoned from what was to be demonstrated to its causes (axioms), both *that* it is and *why* it is were known: a *demonstratio causae et existentiae*. But the natural philosopher knew what the effects were and could only reason to (possible) causes: a *demonstratio causae*. Because the effect itself *qua existentia* was already known, a *demonstratio existentiae* was rare, although one could occasionally be made in cases where cause was already known. Almost never could there be a demonstration combining both.

Pietro agreed with 'Ali that Galen's *analysis* was to be identified with Aristotle's *hoti* or *quia* demonstration. He added, however, that mathematicians only used demonstration *propter quid* or *dioti*, so that what Galen was talking about was *not* the same as the geometer's demonstration. He seemed then to propose that Averroes' *demonstratio simpliciter* was like natural philosophy's *propter quid*, but dispensing with any visibly prior *demonstratio quia*: present in some sense, but hidden from view. Pietro drew from Averroes the idea that this last involved resolution of an 'end' which was a natural 'effect' (whereas for 'Ali the 'end' had been the aim of a whole science). He also added, as the fact that he subsumed *quia* under *simpliciter* would suggest, that *quia* and *propter quid* demonstrations were somehow connected. He did not explain how. Taddeo degli Alderotti (1206/15–95) agreed that mathematicians used *propter quid* demonstrations, but he then went on to explain just how *quia* demonstrations could be connected to them. Once they had 'resolved' effects into their causes, there could then be a *regressus* (he used the word, as did Pietro in rejecting his views) from these causes back to their effects.[17]

Over the next two centuries the debates became intricate, as commentators observed that among the problems with this notion were two major ones: that of circularity (one merely retraced the steps of the other), and that of *petitio principii* (analysis and synthesis, *quia* and *propter quid* demonstrations were syllogisms involving only knowns). Both of these meant that it was not discovery but only pedagogy that was in question.[18] In the *De tribus doctrinis ordinatis secundum sententiam opus* which accompanied his 1508 translation of Galen, Leoniceno thus used this aspect to clarify matters, by distinguishing between the method of teaching and the method of discovery: *modus* or *ordo docendi* and *modus* or *ordo doctrinae*. The first was used to constitute a whole science, the second to solve particular problems or answer specific questions within a science. Although Leoniceno did not say so, this corresponded to the Averroist *ordo* (naming the order of a science) and *via doctrinae* (its method of demonstration), although no one had made anything of the distinction. Leoniceno specified four *modi doctrinae* or *doctrinales* that he claimed to draw from Aristotelians and Platonists alike: definition, demonstration (syllogism), division and resolution.[19] Resolution involved a method for discovering an 'end' that was not an already-existing effect, but an 'end conceived in the mind' – and so had to do with the end of a whole science, the method by which a science was constituted *qua* science.[20]

Also in 1508, Agostino Nifo (1473–1538) offered other attempted solutions. In his commentary on Aristotle's *Physics*, he noted agreement with those who

> are of the opinion that four modes of knowledge [*notitiae*] occur. The first is knowledge of the effect through the senses, or observation. The second is the discovery of the cause through the effect, which is obtained by *demonstratio quia*. The third is the *negotiatio* of that cause by the intellect, by which, in conjunction with the first, knowledge of the cause is increased so that it is worthy to be made the middle term of a *demonstratio simpliciter* [=*demonstratio propter quid*]. The last is knowledge of the reason for the same effect, through a cause [knowledge of which is] so grown that it may serve as the middle term [of the *demonstratio propter quid*].[21]

Nicholas Jardine remarks that what Nifo meant by *negotiatio* was obscure. He later dropped the idea, emphasising that *scientia* of nature was always *coniecturalis*, whose primary meaning Jardine shows to refer to 'the peculiar characteristics of things', that which in nature cannot be otherwise: as smoke indicates fire. Of such we could know, for example, their 'constant conjunction' but not with any certainty the 'proximate cause' of such conjunction. 'To put it in a nutshell', Jardine ends, 'in a *syllogismus coniecturalis* only the *necessity* not the *truth* of the premisses and conclusion is uncertain'. One could do no better in natural philosophy. Regressive *negotiatio* never gave necessary knowledge. One used not Aristotle's *scientific* 'demonstration and conceptual induction', but the methods of the *Topics*: 'contingent, probable, plausible, widely accepted' evidence founding 'sound belief'.[22]

By now, then, while these debates had not been resolved, they had become somewhat considerably clearer. Above all, the important distinctions between teaching and discovery, and between method (*ordo*) as the ordering of particular sciences and method as a way (*via* – Greek *hodos*) of solving particular problems had been made. Further, the debate was now allowing distinctions to be made at different levels of explanation, even if matters still remained obscure. Further, as all these writers made clear, insofar as a major issue was the play between mathematical and medico-philosophical method, it always involved aligning them with each other as forms of *logic*.

At this moment, publication of the *editio princeps* of Euclid with Proclus' commentary (Basel, 1533) set off fireworks across western Europe, writers vying with one another to assert mathematics' capacity to act as a general methodical instrument for all the sciences and struggling over the arguments, pro and con.[23] A little later, the fledgling Society of Jesus began to open its colleges. From the start they emphasised the practical, if not necessarily the theoretical, importance of mathematics. Since the remarkable detective work of William A. Wallace on the intellectual and educational background to Galileo's work, we know, too, the importance of the contacts between, especially, the Jesuits' flagship Collegio Romano and the universities of the Iberian pensinsular, Alcalá, Coimbra and Salamanca.[24]

At the start of his 1554 commentary on Porphyry, Domingo de Soto (1494–1561) asked a set of central questions: does logic come from reason or instinct? is it a necessary science? if so, is it a single science, or even a science at all? is there a separate logic for every diverse series of objects? is it speculative or practical? is the object of logic the being (*ens*) of reason? and then, do universals exist only in the intellect or in things? Quoting Albertus Magnus (1193–1280), he wrote that 'logic begins from nature, but is completed by art'. It was the art 'of discoursing accurately and of reasoning', a perfecting of reason 'necessary for procuring the other sciences'. So, concluded de Soto, 'dialectic has to be learned before the other sciences'.[25] Logic, he held, was a speculative science whose aim was indeed to study the being of reason and that underlay the varieties of thought applied to different objects.[26] This Aristotelian view would continue for a while to stand against the mathematical arguments – although we need to bear in mind that many of those who crossed swords did not think logic and mathematics to be opposed: Peter Ramus (1515–72), for example, ultimately came to think of geometry as logic and logic as geometry – differing from Method.[27] There were, too, many different ways of conceiving their alliance: the arguments were neither simple nor clear – and far from unidimensional.

De Soto seems to have been adapting here a familiar medieval distinction between *logica docens* and *logica utens*, revitalised by the debates we have just seen. But he overlayed it on an older distinction between reason of nature and reason of art. *Logica docens* (others' *modus* or *ordo docendi*) was a science whose object could well be the nature of reason itself, whereas its companion was something more instrumental (*via* or *modus doctrinae*). De Soto now suggested that the study of the being of reason grounded and guided the doing of reason, the art of accurate discourse. After all, reason's being was indeed of nature, while its doing, though natural, could at least be improved by artifice. Perhaps, even, the one corresponded to Aristotle's universal logic, the other to his particular logic. The Jesuit Pedro da Fonseca (1528–99) took this view. There was one logical or dialectical doctrine *disserendi*, of discoursing accurately, and it could be a general basic instrument for all knowledge.[28] In a sense, this steps back from the clarifications of writers such as Leoniceno and Nifo: no clear distinction was being made in practice between different *kinds* of methodical logic, even if it was made in theory. But we will see that the nature/art opposition became important in Zabarella.

In his 1561 logic text, the fruit of teaching at the Collegio Romano, Toleto, who had studied with de Soto at Salamanca before going to Rome, had appeared more closely influenced by the medico-philosophical and mathematical debates: 'Dialectic shows the way [*viam ostendit*] and gives a Method [*Methodum tradit*] by which we can reveal hidden things, clarify confused ones, dispel errors, and confirm truths, thus it is to be learned before every other science'.[29] Students in the grammar and humanities classes of Jesuit colleges had already learned much of *via* as a way of apprehending questions in disciplines, much having been made of it in those classes.[30] It is unclear whether Toleto was trying to distinguish *via* from *methodus*, the one particular, the other general. This '*Method*' was still de Soto's *ars*, the task of which was to complete the natural logic of the mind, and as such would be a general way to order knowledge. It was Aristotle's syllogistic, which Toleto placed after his textbook in the form of Porphyry's *Isagoge* glossed by Boethius (so still in earlier patterns of thought).[31] Nonetheless, Toleto's introductory views surely did seem to have been influenced by the lay debates.

The word *methodus* had been used since at least Boethius, and it occurred throughout the European Middle Ages, along with such terms as *modus* and *ordo*. Each term had many connotations.[32] The Latins had used *via* and *ratio* with essentially the same set of meanings. We have now seen, however, that *via* and *ordo* seemed to be settling into a distinction between method applied to particular questions and method applied to ordering an entire science (although Ramus muddied this, his method being pedagogical, his geometrical logic, as it eventually became, being for discovery[33]). Zabarella would later distinguish between *ordo* and *methodus* – the first meaning general ordering, the second having a much stricter sense tied directly to all these debates, as I shall soon discuss. Toleto, however, already seemed to be seeking to catch a sharper meaning with the same term, *Methodus*: a specific way of organising a natural logic or reason. We now know, of course, that the cross-fertilization between the Collegio Romano and the universities of Spain and Northern Italy was considerable and ongoing. Descartes was among those who benefited.

Toleto's full commentary of 1572 on Aristotle's logic was assigned by the *Ratio* for the first philosophy year – that, or Fonseca's 1564 *Institutiones*.[34] It (they) asked much the same questions as de Soto, and answered much as they both had done before. Dialectic

> is for learning all sciences, for removing all errors, knowing deeply hidden truth, analyzing the nature and essence of things, their principles, causes, parts, properties, and accidents. . . . It opens the way [*viam aperit*] to reasoning about all things, subtly, accurately, appositely, and without deception [*subtiliter, acute, & apposite, ac sine deceptione*].[35]

Clearly, here, Toleto's method was still founded on a traditional ideal of science as *cognitio certa per causas*. Following Aristotle, he divided sciences into speculative and practical. In the first group were metaphysics, physics, mathematics. The second was separated into active (concerning the mind: will, intellect and memory) and factive, which included those treating speech (grammar, rhetoric, poetics and history) and those dealing with external works, the mechanical arts. Dialectic was necessary for all these. It was an 'organon or instrument by which sciences are acquired', and was properly thought a science in its own right, although the latter claim glossed over important difficulties.[36]

The question whether logic was a science in its own right, that is to say, whether it had its own proper and distinct object (de Soto's *ens* of reason, for example), or whether it was closer to an art, simply an instrument enabling one to acquire sciences, was much disputed. Aristotle had left the issue ambiguous. In the *Prior Analytics*, for instance, he had written:

> The method is the same in all cases, in philosophy and in any art or study. We must look for the attributes and the subjects of both our terms [in a demonstrative syllogism], and we must supply ourselves

> with as many of these as possible, and consider them by means of the three terms, refuting statements in one way, establishing them in another, in the pursuit of truth starting from an arrangement of the terms in accordance with truth, while if we look for dialectical deductions we must start from plausible propositions. . . . But in each science the principles which are peculiar are the most numerous. Consequently it is the business of experience to give the principles which belong to each subject.[37]

'Dialectic', he asserted in *Topics I*, 'is a process of criticism wherein lies the path to the principles of all inquiries'.[38] But was it a science – and did it matter? Aristotle did not answer the first question: the answer to the second was affirmative. It mattered because if it was a science it paralleled the others. If it was something else, it might underpin them as some universal rational order.

Important Aristotelian debates took place at Padua and Venice. To Padua, especially, students flocked, adding to the cross-fertilization I mentioned. Zabarella was a major figure, a Paduan who held his university's chair in logic from 1564, leaving it in 1569 to proceed through his university's natural history chairs. His work, well known in his lifetime, grew yet more so especially in northern Europe over the next fifty years.[39] His *Opera logica* appeared in Venice in 1578. He published some later logical works (including a commentary on the *Posterior Analytics*) and writings on natural history, most of which appeared long after his death in 1589. The sum of his arguments was that logic was not a science, but a method of science: a 'metodo scientifico', as Paul Oskar Kristeller translated him.[40]

Zabarella based this claim on the Medieval distinction between first and second intentions. First intentions were ideas referring directly to things that exist independently of humans, such as 'animal' or 'world'. Second intentions, such as 'genus', 'verb', 'proposition', referred to first intentions. These second intentions were made by humans and were contingent, not necessary. Because logic had them as its domain, it could not be a science, whose only objects were necessary things.[41] The same distinction held, of course, for Jesuit claims about the superior certainty, for instance, of mathematics. It was such second intentionality that gave that discipline its certainty, even as it deprived it of the ability to deal with true *causas*. By the same token, physics could treat true *causas*, but only with great uncertainty: this was precisely what the argument about the relation between the 'different' kinds of method, geometers' analysis versus that of the physicians, *quia* versus *propter quid*, *via* versus *ordo* and the rest had been in great part about. When people started to say that such 'true causes' necessarily escaped the capacity of human knowledge (by their difference and distance from mind), and that the best that could be expected was an effective instrumental practice of rational principles, then something had obviously changed radically. That stage had not yet been reached. Nor is it clear that Descartes' work would (or intended to) reach this point, although later interpretation may have made it seem to do so.

'I have always thought the opinion most true', Zabarella wrote, 'that logic is an instrument of philosophy, and that its nature cannot be indicated and explained better or more correctly than by the name of instrument. Thus the nature of logic is an instrumental discipline, or an instrumental *habitus*'.[42] The two instrumental disciplines were grammar and logic, and of the latter there were two: *logica naturalis* and *logica artificiosa*. Here, he was echoing de Soto's view, and a remnant of the *logica docens/logica utens* division may still remain. But Zabarella argued that a true science had to deal with real things, not simply entities of the mind – logic, including artificial logic, could not therefore be a science. It had to be an instrument, and it had to be an instrument of discovery, a *via* or (in his terms) a *methodus*, not an *ordo*. From here he went on to elaborate further.

Natural logic was 'a certain natural instinct, a certain power got through no human study, by which even wholly untaught people make syllogisms and arguments, with no knowledge of the art of arguing'. This logic dated from the origins of humankind, for the earliest sages, 'led by natural instinct itself, observed a certain method for the contemplation of things, and proceeded from certain known principles to unknown ones'.[43] But this logic needed supplementing by a resolutive form of knowing, able to link causes with effects available to the senses, and then derive them from such effects. For Zabarella this was a necessary first step in a double progress towards knowledge. The traditional term for it, we have seen, was *demonstratio quia*, and it was taken by such as the Dominican Tommaso Cajetan (1468–1534), a renowned and widely followed Aristotelian commentator), Leoniceno, Nifo and de Soto simply to give a hypothetical way of describing effects: it did not explain. It gave a particular 'material' grasp of sensible effects. As such, wrote Zabarella in the *De regressu*, it could give only 'confused knowledge' of causes: he called it a *quod* demonstration.[44] As yet, it was barely a 'logic' at all.

Rules of art were needed to connect it with the more perfect 'compositive' or 'demonstrative' logic that built up effects from causes drawn from reason. However natural, such logic could only come second in practice, since it required that mind, originally a *tabula rasa*, have available to it things known only via the senses.[45] Here Zabarella was following Aristotle quite closely, even indeed to the argument of the naturalness of such logic: 'induction [reasoning from particular to universal] is more convincing and clear: it is more readily learnt by the use of the senses and is applicable generally to the mass of men; but deduction is more forcible and more effective'.[46] Knowledge gained via the senses, by resolution or induction, was inevitably less exact than that learned by deduction or compositive logic, which was therefore a better universal instrument. For Zabarella (and all Aristotelians), the fact remained that such logic was necessarily second chronologically, since the senses had first to provide access to things. But true artificial logic had in fact to combine the two.

This was *regressus*. Where resolution provided 'material' knowledge, composition provided 'formal' knowledge. Once the first resolutive step had been taken, the mind as it were looked into itself to find systematic principles into which the initial hypothetical material cause could be set. One might then see that (and how) a formal cause so found did indeed formally account for the effect first known. (Could these become Descartes' 'innate ideas', those first universal causes able to explain sensible and conceptual effects, causes acting, as Toleto put it, '*subtiliter, acute, & apposite, ac sine deceptione*'? – some of his arguments often suggest so.) Composition thus furnished, said Zabarella, using the familiar Aristotelian term this time, a *demonstratio propter quid*. For the combination of these two steps Zabarella used the word apparently coined by Alderotti:

> *Regressus* in fact is a relation between cause and effect, when they interact mutually [*quando reciprocantur*], and the effect is better known to us than the cause; for since we always start with better known things, we first demonstrate the unknown cause from known effect, then once the cause is known, we return [*regredimur*] to demonstrate from it the effect, so that we may know on what account it is [*propter quid est*].[47]

Many writers disputed details of Zabarella's work – a *tabula rasa* which yet has an instinct for rational knowing was a problem – but by and large, sidestepping the terminological issue of 'science', they adopted the instrumental view of logic. A view strikingly similar to Zabarella's was taught by Paulus Vallius (1561–1622) in the late 1580s at the Collegio Romano. He made the *naturalis/artificialis* division, repeated the *regressus* argument and even took over assertions of logic's simple instrumentality, although, perhaps because of his Jesuit context, he was less openly pugnacious about it. In 1583–4, Ioannes Lorinus taught the same ideas.[48] Zabarellan *regressus*, an artificial logical instrument of discovery, a *via* to gather material knowledge by 'negotiating' material effects into rational cause(s) seems to have become as familiar in Jesuit teaching as Fonseca's or Toleto's *methodus*, with which, its greater precision aside, it had many principles in common.

In his 1605 *Logica Mexicana*, a work rewriting one of 1603, the Jesuit Antonio Rubio (1548–1615) likewise took up this now normative view. But he also entered the debate as to whether the mind was a passible *tabula rasa*, or an active instrument, concluding that at least by means of the instrument of demonstrative logic the mind became active.[49] Did this argument help solve the *tabula rasa* problem? It did give a series – mind, natural logic, artificial logic, acquisition of knowledge – whose first two elements, which were virtually identical, led directly to a third, which simply improved the second: in the same way that Descartes' future 'method' would improve his 'good sense', both, we shall see, coming after the mind's 'natural light'. This particular form of exposition was not crucial in these debates, but the fact remains that it strongly implied that, if natural logic (syllogistic for Toleto and Zabarella) was inherent in the mind, the artifically developed method of *regressus*, linking exterior to interior, became the crucial means to efficient instrumental knowledge.

It also seems clear that to insist on logic as a rationally organised *instrument* tended to remove it from any place in the traditional sciences of 'presence', and 'real causes', those that consisted, as Aristotle's and Aquinas' successors still held, 'in certain, universal, and unchanging knowledge achieved through causal demonstration'.[50] Nifo's final claims had seemed to invalidate the demonstrative syllogism as a means suitable to natural inquiry. Many others had already in practice restricted its use to communication. But if this was so, then other means of discovery were needed: which may explain why Ramus' 1572 *Dialectica* emphasised what one may call a 'geometric turn'. It may also explain a difficulty in Zabarella's 'return' to Nifo (via, it seems, a more immediate predecessor in Girolamo Balduino (fl. 1549–70), an older colleague of Zabarella at Padua).[51]

Unlike Nifo's, we saw, Zabarella's regressive method relied on three, not four, steps. No special place was given to initial observation. And if Jardine deems Nifo's *negotiatio* obscure, he holds Zabarella's to be 'bizarre': he

> supposes that observation gives rise to images which merely serve to make the rational soul (*intellectus passibilis*) receptive to simulacra of the knowledge present in the mind of God. The vehicle for this inspiration of fragments of God's knowledge is *intellectus agens*, the Holy Ghost.

Negotiatio was the means by which the human mind worked through the relations between 'the simulacra of the ideas present in the mind of God which constitute the things of the external world' and those 'inspired into the human mind through the agency of *intellectus agens*'. It was this that took one from a *quia* to a *propter quid* demonstration. This notion is far from anything we could recognise today as 'scientific method', and belongs in a mental world in which embodied passible souls were linked by memory and its recovery to an impassible universal soul.[52] One can see how this corresponds to Rubio's and others' question about a passible *tabula rasa*. Instrumental logic, that of *regressus*, activated ideas of causes always and already latent in passible mind (which is how they were also 'good' or 'common' sense). That is why Zabarella held the natural knowledge produced by this process to be certain and to explain the universal ground of specific phenomena, to give us what Francis Bacon would name *experientia literata*, literate experience.[53] While distinct from the knowledge expressed in the syllogisms of 'natural logic', it still had nothing directly in common with a 'geometrical method'.

In other ways Zabarella's distinction of a natural and an artifical logic corresponded to another distinction soon to be made: that between experience and experiment, between (in something like his terms) effects merely passively imprinted on the mind and effects subjected to the operations of *regressus*. Thus, the Jesuit mathematicians Christopher Scheiner (1573–1650) and Josephus Blancanus (1565–1624), for example, distinguished respectively between 'phenomenon' and '*experientia*' and between 'phenomenon' and 'observation'. By observation and *experientia*, Blancanus and Scheiner meant Bacon's 'literate experience', the result of a ruled *experimenta*, a 'particular procedure whereby the experience may be instantiated'. For both, 'phenomenon' named something generally known, while the second required specially devised rational instruments.[54] This was the distinction Zabarella made between his logics: the one was composed of untaught 'syllogisms and arguments' and available by its very *nature* to the passible mind, the other, regressive logic, was learned rule. This was no mathematical solution to the problem of methods of discovery, yet it was as distant as these from the syllogistic canons once, but no longer, thought sufficient for such ends. Regressive method was ruled in the same sense (if not necessarily in the same way) as the natural knowledge associated with it. To be sure, it *used* no element of Scheiner's, Blancanus' or Bacon's still vague idea of contrived experiment.[55] But it was *itself* such an artificial device for an ordered rule.

Zabarella was careful to separate both logics from '*ordo*'. He used this word to name the simple systematic ordering required in teaching, and specifically rejected the idea that 'method' was for teaching, presumably with the Ramists in mind and perhaps, too, its growing association with geometry. He made it clear that the regressive method was for discovery: a 'functional, intellectual framework which serves in the acquisition of correct knowledge'. Scepticism as to humans' 'ability to obtain knowledge of causes' had disappeared – here, at least.[56] Zabarella, as Heikki Mikkeli observes, saw method as a way to reconfirm Aristotelian claim and argument.[57] To do so, however, he emphasised the distance between a 'natural' syllogistic reasoning and an 'artificial' contrived reasoning suitable to natural knowledge. His solution to the dilemmas we have been following is especially valuable precisely because of its sustained effort *not* to break with past habits of mind. His rejection of mathematical reason in discovery went against a deepening grain.

But if Zabarella and future 'scientific' thinkers differed on *what* and *how* one could know, they disagreed far less on claims about the obstacles that lay before knowing. And on issues of the instrumental *via* of method and of two logics, Zabarella fought on grounds he shared with de Soto, Fonseca, Toleto, the Coimbran commentators and many others, including Descartes in the *Regulae*. Whether one distinguished nature and artifice, *intuitus* and intellect, or even deduction and induction, the traditional play of compositive and resolutive had somehow been adjusted to encompass a new organisation of experience and reason.[58] The relation between experience, perception of a material history and mathematical rule that others were seeking and forging remained foreign to Zabarella, even though he was not less conscious than others of the seeming insuperability of the obstacles set before natural knowledge in their inherited ways of thought. To ever more thinkers, the solution was increasingly understood to be found in mathematics. The move towards making mathematics in some way foundational was already under way, although again, I emphasise, this cannot yet be separated from the debates about 'logic' and method whose detail has just been presented. The Jesuits were at the forefront of those who sought to integrate the speculative instrumentality of mathematics (rationally the most certain of techniques) with courses in natural philosophy as early as the 1580s.[59] It is here that we can at last return to Descartes.

The last passage I quoted from Zabarella's *De regressu* (see page 207) was the one that Poisson had more or less paraphrased in the passage with which I began. The question there was whether, as Poisson more than implied, it described at all what Descartes was doing. It is with that question that I now draw these strands towards a conclusion, replying to it with an emphatic 'yes'.

Answering the second Objections to the *Meditationes* (compiled by Mersenne) in 1640–1, Descartes remarked that contrary to the objector's view, he had in fact followed the 'geometers' manner of writing', but that he had done so only as far as he thought it useful. It had, he wrote, two aspects: 'the order and the means of demonstration'. 'Order' was the rule that 'things put forward first must be known without the help of what follows, while those following must be so arranged as to be demonstrated only by what precedes'. One could argue that this was not very different from Zabarella's *ordo* (to say nothing of syllogistic): an intensional logic of deduction from known 'causes', permitting (taken alone) pedagogical or demonstrative presentation of a whole science, but not originating discovery. It *might* be influenced by the 1637 *méthode*, but it clearly reflected the older debates. Descartes then added that there were, however, two kinds of demonstration: 'by analysis' and 'by synthesis'. Claude Clerselier's 1647 French rendering, verified by Descartes, glossed these terms by adding 'or resolution' and 'or composition' respectively.

But his explanation was less clear. 'Analysis', read his Latin, 'shows the true path by which a thing has been discovered methodically and as it were *a priori*'. To this the French added the ambiguous explanatory phrase: 'showing how effects depend on causes [*comment les effets dépendent des causes*]'. On the other hand, synthesis worked 'by a contrary path [*per viam oppositam*]': 'one seeks as if *a posteriori* (although the proof itself is often more *a priori* than in the analytic)'. The French translated '*a* *posteriori quaesitam'* as 'examining causes by their effects', and then followed the Latin in noting its use of 'a long series of definitions, postulates, axioms, theorems, and problems', each deduced from the preceding.[60] Most commentators have seen problems here. Descartes' 'analysis' was the opposite of the Aristotelians', which went from effects to causes, and for whom a priori meant, on the contrary, a reasoning from cause to effect, as we have already seen. (Descartes' version was also the opposite of Poisson's explanation – see above.) At the same time, Descartes' 'synthesis' was at once the opposite (again, in contrast to the Aristotelians) and yet not, since its deductive sequence also matched their idea of it. He may just have wanted to say that its a priori proofs (cause to effect) were a posteriori in the sense that the whole procedure came *after* the first steps of analysis, which, as we have seen, all Aristotelians insisted to be the case – even though, while doing so, their idea of analysis was quite different. It is therefore this last that we must first try to explicate.

For in any case, Descartes asserted that while the ancient geometers used synthesis that was only because they held analysis so highly as to have wished to keep it secret. Analysis was 'the best and truest way of instruction'. That was why he preferred to use it alone.[61] The choice is revealing. For Descartes, the two were *not* interdependent, but both had acquired aspects drawn from *regressus* theorising. As described here, synthesis alone involved deriving knowledge from effects but emphasised demonstrating them from causes: it taught or showed the results of analysis. In a way, the complications of Descartes' explanation echoed those of Toleto and Zabarella as quoted and paraphrased by Poisson: his idea of synthesis had absorbed *regressus*. But it also remained just a means of communication: what the ancients used only 'in their writings'. Analysis, however, had become something very like Descartes' Method, and it could do so because it, too, had learned to make regressive use of 'resolution'. Descartes used a phrase very like Toleto's referring to opening a way and providing a method: 'Analysis', he wrote, '*veram viam ostendit per quam res methodice & tanquam a priori inventa est*', terms which were imbued with memories of his School years.[62] But *via*, *methodice*, and *a priori* were combined here into something new. Our difficulty in understanding what Descartes was describing comes, it seems to me, from the fact that he was not simply taking the older, simpler, terms of art (analysis/resolution versus synthesis/composition), but, putting them through a Toletan or, better, Zabarellan filter, was making something different (and more complicated) out of them.[63]

Descartes' Reply actually repeated terms that went back to early discussions of the same issues. In 1619, in the earliest part of Rule 4, Descartes had written on how the ancients had, 'with a kind of pernicious cunning', suppressed the mathematics that had allowed such ancient geometers as Pappus and Diophantus to make their discoveries: a kind of *mathesis universalis*, he said, whose meaning in Greek was that of 'universal *disciplina*

[= *mathesis*]' and which was to be imagined as common to every kind of doctrine 'concerning order and measure irrespective of the subject-matter'. Descartes asserted that applying this *mathesis* first in the most obvious domains would then enable him to go on to 'the somewhat more advanced sciences' – ordered in a systematic philosophy which, he commented later in the preface to the French *Principes de philosophie* (1647), would end in 'ethics'. In a part of the same Rule 4 that may have been written later, Descartes emphasised that this *mathesis* was a 'sort of analysis' that the ancients had 'begrudged revealing ... to posterity'. These were terms he still used in replying to the Second Objections. In Rule 4, as in 16 and 18 that may date from nearly ten years later, Descartes urged further that modern algebra, in the certainty and distinctness with which it systematically and transparently tied known to unknown quantities and above all in the fact that its equations directly explicated *material* relations and proportions, *was* that ancient analysis.[64]

Peter Dear has argued that by the 1637 *Géométrie*, Descartes 'had come to adopt a new position' for this claim of Rule 4 that he was rediscovering the ancients' analysis, and that because 'he could now solve problems that had thwarted the ancients, his symbolic algebra must be something new'. It was indeed the case that Descartes there asserted that if ancient geometry had been as advanced as his, its authors would not have needed to reveal its discoveries via synthesis: taking 'the trouble to write so many huge books about them, in which the very order of their propositions shows us that they did not have the true method [*la vraie méthode*] of finding them all, but that they just gathered those they came across'.[65] Yet Descartes never argued that his method was new. Even if he had now been able to take it further than the ancients had, the fact remains that in the *Second Replies* he emphatically repeated his older claim: that the reason why the ancients disordered their account in *teaching* its results (making it echo later synthetic demonstration) was to *hide* the efficacity of their instrument from those who might abuse it – shades of the 'Fathers' of the scientific Salomon's House of Francis Bacon's *New Atlantis* who, however, hid *their* knowledge for the sake of 'profitable' interest.[66] What Descartes *did* now suggest in the *Discours de la méthode* and its companion essays was that once one recognized the ubiquity of good sense in humans (indeed, as defining of them) then method, 'analysis', could be put to good use by all, no longer *needing* concealment.

In this regard, the Reply to the Second Objections repeated other passages from the 1637 *Discours*. In particular, it echoed the moment in the sixth part where Descartes wrote of having found 'a path [*chemin* = *via*] which [he] thought would inevitably lead' to his indispensable '*science*', length of life and sufficiency of observation permitting. But this depended on 'discovering in general the principles or first causes of all that is or can be', looking nowhere but in 'God alone, who created [the world]', and drawing these principles only 'from certain seeds of truths that are naturally in our souls'.[67] These 'sparks of knowledge', 'spark of the divine, in which the first seeds of useful ways of thought are sown' (however stifled later by the wrong kind of study), had also been present from Descartes' earliest writings, the *Olympica* and again Rule 4, from 1618–9. He repeated the thought in a letter to Mersenne in 1630, and it was something he in fact often reiterated.[68] It remained central to his arguments in the third and fourth *Meditationes* as the *lumen naturalis* which at once shows us what is a 'primary idea', *is* such an idea (or perhaps its 'archetypal' cause) *and* the ground of the 'faculty of judgment . . . received from God'. It was the *magna lux* of the intellect guiding the will, a *lumen naturalis* limited only in comparison to the infinite powers of God.[69] Nor was '*lumen naturalis*' just a metaphor. As Descartes scornfully enjoined in his Reply to Hobbes, it accurately named the transparent clarity of human understanding.[70] In their earliest forms, as seeds or sparks, this *lux* and *lumen* remind me of nothing so much as of Zabarella's passible mind in which the seeds of knowledge were brought to light by properly applied regressive logic.

These seeds were an essential part of Descartes' argument about his analytical method and its order and about its not being subject to the criticism of being circular. He was concerned to refute this possible attack as he concluded the *Discours*, doing so in words that at first look as if he could have drawn them almost unchanged from Toleto or Zabarella:

> If any of the things I have said at the beginning of the *Dioptrique* and the *Météores* shock at first, because I call them suppositions and do not seem to care about proving them, be patient enough to read the whole book attentively and I trust you will be satisfied. For I take the reasonings [*les raisons*] to follow one another in such a way that as the last are demonstrated [*démontrées*] by the first, which are their causes, so these first are reciprocally demonstrated by the last, which are their effects. Nor must it be thought that I commit here the fallacy [*la faute*] that logicians call a circle; for since experience [*expérience*] makes most of these effects very certain, the causes from which I deduce them serve not so much to prove as to explain them; rather, quite to the contrary, it is the causes which are proven by the effects. And I have called them suppositions only to make it known that while I think I can deduce them from those primary truths I explained above, I deliberately wished not to do so, so as to prevent certain wits from taking that as an opportunity to build on what they believe to be my principles some extravagant philosophy for which I shall be blamed.[71]

Descartes was saying here that while he *could* have done as the ancients and synthetically elaborated his demonstration, he chose rather to show the *regressive* demonstration itself: analyzing effects as observed (by *expérience*) via causes whose *explanatory* validity was only *proven* by the fact of the effects themselves.

In letters to Vopiscus Fortunatus Plempius (1601–61), where he replied to the latter's objections about the 'circle' after he had read the *Discours*, Descartes repeated the point, detailing his argument with perhaps greater clarity than he managed in the later *Reply to the Second Objections* which these letters exactly anticipated. Here, he tied analysis directly to the idea that the effects at issue were those '*material* relations and proportions' which I named before: 'I used only very evident principles, and like a mathematician I took account of nothing but sizes, shapes and motions, and so I cut myself off from all the subterfuges of philosophers'. Again, *material effects* let principles (*causes*) be verified (a claim which also went back to the last *Regulae*). Even though such principles had explanatory power, it was they that were to be corrected by the 'mathematical demonstration' from these effects whenever some 'error' occurred which these effects, too, would reveal.[72]

Descartes further emphasised the point in another letter to the same correspondent two and a half months later. After saying that anyone wishing to understand his demonstrations needed to understand that the propositions with which they began were only proven by what followed, since the first were not '*mea principia . . . sed potius sunt conclusiones, quae per sequentia omnia demonstrantur* [my principles . . . but are, rather, conclusions demonstrated by everything that follows]', he ended by trying to show just what this meant:

> Sizes, shapes, positions and motions are my *formal* object (in philosophers' vocabulary), and the physical things which I explain are the *material* one. For the principles or premisses from which I deduce these conclusions are only the axioms on which geometers base their demonstrations: as, 'the whole is greater than the part'; 'if equals are taken from equals the remainders are equal'; and so on, but they are not abstracted from all sensible matter, as in geometry, but applied to various experiential data known by the senses and indubitable. For instance, from the oblong and inflexible shape of the particles of salt, I deduced the square shape of its grains, and many other things which are obvious to the senses; I wanted to explain the latter by the former [the actually observed effect] as effects by their cause. I did not want to prove things which are already sufficiently known [i.e., actual 'experience'], but rather to demonstrate the cause by the effects *a posteriori*.[73]

What Descartes wrote here was just what he was to repeat in explaining synthesis as *a posteriori* in 1641: the supposed square shape of the grains was to be 'explained' by or 'deduced' from the oblong and inflexible shape. The square shape was the formal *effect* of a material *cause*, the visible oblong shape. What one knew indubitably (or *satis*: *qua* sense perception) was taken as a cause to reach what in synthesis would be imagined as an a priori cause but in analysis was recognized as an effect of the material cause. So 'sizes, shapes, positions and motions' stayed attached directly to 'sensible matter', always to be considered primary and most evident. Doing this was, exactly, *not* to prove (*probare*) known effect – from Nifo to Zabarella deemed not possible – but to demonstrate (*demonstrare*) what synthesis would take as cause (the underlying crystalline form of salt) by means of its visible, experienced effect, the oblong and inflexible shape. Such was the analysis that preceded any synthetic presentation of conclusions, whose form Descartes ultimately felt secure enough to present and practise (he said) in the *Essais* accompanying the *Discours*.

He again insisted on the explanatory/probative play of regressive analysis seven months later in a letter to Morin, the mathematician who may have authored or, at least, been behind the Second Objections, and who also criticised Descartes for arguing in a circle. Morin reproached Descartes for holding 'back knowledge of the principles and universal notions of [his] physics . . . and basing [his] reasonings only on probabilities [*comparaisons* = *comparationes*] or assumptions [*suppositions*] of the truth'. To this Descartes could legitimately reply, as he effectively had to Plempius, that such principles and universals could only come *after* their proof by material effect and that part of his effort in the *Essais* following the *Discours* had been to provide such 'proof' – or at least evidence for it. But Morin argued that without knowing these principles, Descartes' reader had no way of seeing that he was not involving himself in circularity: 'For if it is true that to prove effects by a given cause, then to prove this same cause by the same effects, is not a logical circle, then Aristotle misunderstood it and one may say that none can be made'. And Morin went on to assert that for this reason the suppositions of astronomers (as to the earth's motion or lack of it) could never let them avoid such logical circles, since 'to prove that the cause of an effect is its true and unique cause, one must at least prove that such an effect can be produced by no other cause'.[74] In his long letter, Morin then continued to show what difficulties this posed for Descartes' exploration of light in the *Dioptriques*.

Descartes replied to Morin in a yet longer letter of 13 July 1638, which he disarmingly began by agreeing that astronomers' *suppositions* indeed did not permit any clarity in deducing cause from effect and that to prove effects by a cause and that cause from the same effects was indeed a logical circle. He simply disagreed, as he had with Plempius, that he was doing this:

> You say also that *to prove effects from a cause, and then prove the cause by the same effects is a logical circle*. I agree: but I do not therefore agree that it is one to explain effects by a cause and then prove the cause by the effects; because there is a great difference between *proving* and *explaining*. I add that the word *demonstrate* [*démontrer*] can be used to signify either, if it is taken according to common usage and not in the

> technical sense philosophers give it. I add as well that it is not a circle to prove a cause by several effects that are known otherwise, and then similarly to prove other effects by this cause.[75]

Descartes then cited the passage from the end of the *Discours* that I quoted above (p. 213). He remarked that although he had there elided these two senses of *démontrer*, he had not been ambiguous, since he had made clear how experience allowed one to *prove* causes by effects but then to *explain* the latter by the former, something one can do all the better when effects have first been multiplied by experience: 'But even if there are truly several effects to which it is easy to fit different causes, one to each, yet it is not so easy to fit a same cause to several different effects, if it is not the true one from which they come'.[76] With Mersenne joining in, this exchange continued for the next four months, eventually focusing mostly on experience of effects.

Nicholas Jardine, writing of the brief version given at the end of the *Discours*, opines that such analysis was only 'an echo of *regressus*: Descartes was noting something like a hypothetico-deductive method in which the postulation of a few causes is justified by success in explaining a wide range of effects'.[77] In a sense, the objection does not affect my point, since it would suffice that Descartes' analysis be an 'echo'. But I think Jardine is not altogether exact, at least as to what Descartes *thought* he was doing. We see him constantly insisting that not the explanatory success of the causes but the probative success of the effects *insofar as they could be so explained* was what mattered in a mathematical analysis. This view may be hard to grasp because it is so unfamiliar: observed effects *proved* the reality of the 'seeds' implanted in the mind by showing that (and how) the 'principles' drawn from them could explain the effects.

Such analytical principles were only shown to be certain by the proof of embodiment in observed effects. In no way did *they* prove that embodiment or anything about it, and conclusions one might draw from any particular embodiment in observed effect were clearly much less certain. Contrary to what many suppose, principles did not give rise to effects.[78] They *explained* effects, but only, so to speak, if the effects let them. These principles – 'hypotheses', as they often were – answered to so infinite a variety of effects in the world as might make them quite uncertain: much as was 'synthesis' in the later Reply – and for similar reasons. Hypothetico-deductions based on principles or causes could only become certain when incorporated in the analysis from effects.

Analysis or method was a new road or *via*, as Descartes named it together with the Toletos and Zabarellas, from which he made an appeal (as in the *Discours*) to everyone's natural reason: to those 'primary notions' that 'agree with our senses' and 'are readily accepted by everyone'. But one had always to keep in mind that it was agreement with the senses that had priority, and that the primary notions, causes or principles in question got proof not just of their validity but of their very existence from the material effects made available to us by those senses. This was the analytical sequence that Descartes again recalled in replying to Mersenne (or Morin): 'There is no difficulty [in rational knowledge], save in properly drawing consequences, which can be done by even the least attentive of people, provided they remember preceding things'.[79]

Descartes had made a revised analysis of the Method of the *Discours*. He had done so thanks to the hierarchies of science and the struggles over method and logic that had been so much of the School debates. The hierarchies had been and remained basic, as Descartes' presentation of his own systematic intentions in the *Lettre-Préface* to the *Principes de philosophie* showed. They remained so because the whole purpose of method had been to unite the various forms and objects of knowledge under one foundational ordering process, marking humanity's divine possession of one reason. I have tried to show how Descartes' 'analytical' method also remained tied in form and object to older intentions: to prove causes by an analysis derived from effects was surely in some serious way to set *logica naturalis* inside the operation of a more efficient *logica artificialis* learned by rules of art – method correcting good sense. What it offered was not just a manipulation of material nature, but an understanding of ordered divine purpose as present simultaneously and reciprocally in the mind and the world as the 'sparks' or 'seeds' of knowledge of the early writings, as the *lumen naturalis* of the *Meditationes*. This idea of analysis did not reduce the benefit to humankind, but subordinated material benefit to a wider aim that had always been as much that of Descartes' as of the Jesuits' enterprise: the human community concordant within itself and in its relation to the wider sphere of world and universe.

Epilogue: Method and Modern Science?

Perhaps it may not be so clear, however, that Descartes' insistence on the probative success of effects – insofar as they are to be explained – *is* so unfamiliar to us. To the extent that what they are 'proving' is an elaboration of principles as '*semences de vérités*' set in our minds by God, and thus more than merely an 'echo' of Zabarella's seeds of knowledge set in the *intellectus passibilis* by *intellectus impassibilis*, they certainly are. But we can read this as a different kind of 'turning', that of the residue of an exhausted way of thinking into the elements of a new one. For it matters that the brief version of method given in the sixth part of the *Discours* is something considerably other and more than that.

In the second part of the *Discours*, Descartes had set out the method that would enable us to avoid the problem that he had set out in the first part. This was that although all humans shared the same 'good sense or reason', we nonetheless all '*conduisons nos pensées par diuerses voyes*' (conduct our thoughts by different paths)'.[80] The '*droit chemin* (the right or straight path)', allowing us to reason rightly and '*marcher auec assurance en cete vie* (walk with certainty in this life)', *knowing* '*les chemins que* [*nous deuions*] *suiure* (the paths we ought to follow)',[81] was what he said he was presenting in the second part as '*la vraye Methode pour paruenir a la connoissance de toutes les choses dont mon esprit seroit capable* (the true method for achieving the knowledge of everything my mind would be capable of)'.[82] Familiarly, this method consists in four steps: (1) to accept as true only things totally clear and evident to the mind, (2) to divide the difficulties of a problem into as many parts as possible and useful, (3) to conduct thoughts in order, going always from simple to complex ones, (4) to run back and fro over the entire process so as to be sure all the steps were clear and nothing was omitted.[83] As most commentators have observed, this is hardly a 'scientific method'. It is rather a natural way to order '*le bon sens*' and in fact bears the mark of nothing so much as Zabarella's natural logic.

It is, however, *not* the same as the method at which Descartes arrived in the sixth part and whose virtues and complexities he sought to explain to Plempius and Morin in 1637 and 1638 in ways that entirely match the argument of the 1642 *Second Replies*. This 'second' method, I suggest, corresponds to Zabarella's artificial logic, but *already* adjusted in the ways I have shown in the course of the *Replies*. More importantly, by that adjustment (or clarification) they go far towards offering a modern scientific method, one that the beginning of the first 'essay' of the method, the *Dioptrique*, confirms. This 'second' method must, then, be cited in full:

> Firstly, I tried to find in general the principles or first causes of everything that is or can be in the world, without considering anything to this end except God alone, who created it, or drawing [these principles] from anywhere but certain seeds of truths that are naturally in our souls. After that I considered what were the first and most ordinary effects deducible from these causes: and it seems to me that by this means I found heavens, stars, an earth, and even, on the earth, water, air, fire, minerals, and some other such things, which are the commonest of all and the simplest, and therefore the easiest to know. Then, when I wished to descend to those which were more particular, so many different ones offered themselves to me that I did not think it possible for the human mind to distinguish the forms or species of body that are on earth from an infinity of others that could be there if it had been God's will to put them there, or, therefore, to make them useful to us [or: relate them to our familiar experience], except by getting to causes via effects and making use of many particular experiences/experiments. As a result of which, running my mind back over all the objects that had ever presented themselves to my senses, I dare say that I have never noticed anything in them that I could not quite readily explain by the principles I had found.[84]

Perhaps the first step that Descartes describes here, the finding of principles in the 'seeds of truths' planted in the mind, corresponds in *some* way to the clear and evident knowledge of the Second Part's method. But it would be much better to say that he describes an establishment of hypotheses. For the second step in fact corresponds exactly to what he describes as 'analysis' and '*a priori*' in the *Second Replies*. It is a deduction of effects from 'causes'. As such, though, as Descartes goes on to say, this process requires considerable correction: both by himself and, as he says many times in this Part VI of the *Discours*, by a community of like-minded scientific interlocutors. Clearly, *this* second step has nothing to do with the second step of the earlier method, division of difficulties, though it may echo its third, thinking rightly from simple to complex. Even were it just a matter of changing the order, the change would be momentous. For now, something like a sorting of difficulties comes *after* the initial hypothetical deduction. And here Jardine is simply wrong to say that the postulation of a few causes is justified by success in explaining a wide range of effects. It *may* be eventually, but is not just yet.

Describing the deduction of *actual* effects, Descartes describes not *Le Monde* or Part V of the *Discours as we have them*, but what initially he described as the elaboration of the '*fable*' by which he arrived at what he ultimately *sorted out* into the later published writings. The analysis of the second step, he wrote, gave him 'des *cieux*, des *astres*, une *Terre*': not *the* heavens, *the* stars or *the* earth, but possibilities of heavens, stars and an earth. Further, his deductions – let us now call them frankly hypotheses – gave him so vast a number of different things, that he no longer had any way to know which might exist and which did not, except only by the third step of submitting the 'causes' or principles of deduction to the effects which could be tested by one sort or another of experience or experiment. At this stage of the process, that is to say, Descartes has *a* world which not only does *not* correspond to the world of our experience but in which he has as yet no means to distinguish true and false ('true' meaning here, as he says, what can be related to '*notre usage*', having nothing to do with quiddities or '*necessities*'). So the third step of starting to verify the correctness of the hypotheses describes the process by which we can begin to sort these things out. Only after that can he come to the fourth (synthetic) step of verifying 'principles', effects and the relation between them.

But Descartes is so concerned about the importance of the third step that he immediately comes back to it, trying further to clarify its point:

> But I must also admit that the power of nature is so ample and so vast, and that these principles are so simple and so general, that I almost no longer notice any particular effect that I do not know right away is able to be deduced from them in several different manners, and that my greatest difficulty is usually to discover in which of these manners

> it depends on them. For to this end I know of no other means than again to seek experiments [or experiences] of such a kind that their outcome will not be the same if it is in one of these manners that it is to be explained, or in another.[85]

This is quite clear. Once the principles – hypotheses – are allowed into the real world they are vastly overdetermined. So the third step must be to test the hypotheses 'by' effects, to see whether they in fact 'produce' (and reproduce) the familiar and recognizable effects described and whether they allow us actually to use effects in the way they predict (the two possible meanings of '*rapporter à notre usage*'). So now Descartes has incorporated experiences or experiments (or observations) which will let effects 'prove' the accuracy of these predictions and of the hypotheses behind them.

The process is precisely that described in the *Second Replies* as it is also that explained in the letters to Plempius[86] and Morin[87] cited earlier. It is, however, also the process that he justifies in the passage from the end of the *Discours* explaining how the reader should approach the three *Essais* in terms of a reciprocal 'demonstration' of 'causes' and 'effects', where Descartes had explained that these 'causes' can only be proven by effects, never the opposite.[88] So let us indeed now call these causes the hypotheses that they are. For, as he wrote to Plempius and Morin, while their validity is pragmatically *proven* by material effects (via '*expérience*') it is only so proven in that they *explain* those effects – give, as he also writes in the passage at the end of the *Discours*, '*reasons*' for them. But these reasons are only reasons in the sense that they let us '*les rapporter à notre usage*', predict them, reproduce them, use them.

This is just what he repeats in the *Dioptrique*, asserting that there is no need 'to try to say what is really' the nature of light – and indeed he could not. On the contrary, he will 'imitate', he writes, 'astronomers', whose 'suppositions are almost all false or doubtful', but yet, because 'they relate to [*se rapportent à*] different observations they have made', allow them 'to draw many consequences that are very true and very certain'.[89] Descartes' use of the same verb to explain the relation of astronomers' observations to their hypotheses (those '*suppositions*' whose meaning he explained at the end of the *Discours*) as he did to explain the general relation of reasons to effects in the *Discours* is not accidental. Here too hypotheses are properly *provisional* – in the same sense as the '*morale*' of Part III of the *Discours* is '*par provision*': they function by allowing the knower to get to a known such that what does not work, what is not 'true', can be discarded, while what does and is can be further extended as it is (or is not) validated, proven by the real 'consequences' or 'real effects' in the world.

That is surely why Descartes began the *Dioptrique* in two remarkable ways. The first is its opening sentence – which should make all interpreters of Descartes as a simple idealist think twice; the second is his deliberate adoption of Galileo's telescope as his entry into discussion. The opening sentence is: '*Toute la conduite de nostre vie depend de nos sens*': the entire conduct of our life depends on our senses. It continues that because sight is 'the most universal and most noble' so it is that any 'discoveries [*inuentions*] that work to increase its power are the most useful possible'.[90] This remark leads Descartes naturally into contemplation of those 'marvellous glasses which, though in use for but a short while, have already discovered for us new stars in the sky and new objects beneath the earth'. Indeed, he went on:

> bearing our vision much further than our ancestors' imagination usually carried, [these telescopes] seem to have opened the way for us to attain a far greater and more perfect knowledge of nature than they had.[91]

The telescope rapidly became not just a metaphor for the new reason (eye-instrument-world; *cogito-ergo-sum*) but an explanation of it.[92] It actually expressed the relation between phenomena, instrumental experience of or experiment on them and understanding/reason. Indeed, Frege again used it in exactly this way at the end of the nineteenth century in 'Über Sinn und Bedeutung', as Hegel did at the beginning of that century in the Introduction to the *Phenomenology of Mind*. It is no accident then that Descartes begins by comparing the telescope to the imagination, saying that it may improve rational processes just as it may increase the power of our sense of sight. Unfortunately for the time being it indeed only *seems* to have done this, or rather, as he again echoes the opening of the *Discours*, to 'have opened the path to a greater and more perfect knowledge of nature'. It only *seems* to have done so because it was discovered by pure 'experience and chance'. To become an efficacious instrument of reason – a useful mediator between experience and hypothesis or effect and instrumental knowledge – we have to know how and why it works as it does and so both what kind of effect *it* is and what is the usable truth of the effect to which it gives us access. That, he writes, is the purpose of the *Dioptrique*. Descartes, then, says nothing but the truth when he says this *Essai* is a demonstration of the method. It is a demonstration of the second method as put forward in Part VI of the *Discours* and explained in so many other places between 1637 and 1642.

But surely this dialectic between hypotheses, worldly phenomena, verification, new hypotheses and so on, to knowledge of *true* events in the world, insofar as 'truth' is just their predictability and reproducibility, describes the methods of modern western science? Indeed, this process describes what this science *is* and does. In these debates about method as they end up in Descartes, the old sense and understanding of *scientia* as *disciplina*, the diverse ordered fields of knowledge, was transformed into a new idea of *science* as explanation of the natural world such that humans could manipulate and practice upon it in predictable ways, making us '*comme maistres & possesseurs de la Nature*,' [93] doing so for society's 'common good' as Descartes repeatedly put it in Part VI of this same *Discours*. Out of the debates on method Descartes had developed the idea of later western science and the technology accompanying it.

Notes

1 Randall's essay was published in *Journal of the History of Ideas* 1 (1940), 177–206, reprinted in his *The School of Padua and the Emergence of Modern Science* (Padua, 1961), 13–68, and in Paul Oskar Kristeller and Philip P. Wiener, eds, *Renaissance Essays: From the Journal of the History of Ideas* (New York, 1968), 217–51. Further ramifications of the debate Randall provoked are addressed below.

2 The bibliography on Descartes' *méthode* and mathematical thinking is of course huge. I cannot rehearse their lineaments here. Until recently, most commentators accepted Descartes' evaluation that he was making a flat break with the past – or returning to an ancient Greek art lost until he recovered it. Most works I have used are noted at their appropriate point, but see, too, Giovanni Crapulli, *Mathesis universalis: Genesi di un'idea nel xvi secolo* (Rome, 1969); Angelo Crescini, *Le origini del metodo analitico: il Cinquecento* (Udine, 1965); Chikara Sasaki, 'Descartes' Mathematical Thought', PhD diss., Princeton University, 1989; Hermann Schüling, *Die Geschichte der axiomatischen Methode in 16. und beginnenden 17. Jahrhundert (Wandlung der Wissenschaftauffassung)* (Hildesheim, 1969); and John A. Schuster, 'Descartes and the Scientific Revolution, 1618–1634', 2 vols., PhD diss., Princeton University, 1977.

3 'J.-B. Morin and the Second Objections', in Roger Ariew and Marjorie Grene, eds, *Descartes and His Contemporaries: Meditations, Objections, and Replies* (Chicago, 1995), 63–82.

4 Garber, 'Descartes and Method in 1637', in Arthur Fine and Jarrett Leplin, eds, *Proceedings of the 1988 Biennial Meeting of the Philosophy of Science Association, vol. 2: Symposia and Invited Papers* (East Lansing, MI, 1989), 225–36.

5 'Dédicace du placard de licence en droit soutenue par Descartes le 21 décembre 1616 à Poitiers', ed. and trans. Jean-Robert Armogathe et Vincent Carraud, *Archives de Philosophie* vol. 50 (Jan.-March 1987): *Bulletin Cartésien* 15, 1–4; 'La licence en droit de Descartes: un placard inédit de 1616', ed., trans. and comm. Jean-Robert Armogathe, Vincent Carraud and Robert Feenstra, *Nouvelles de la République des Lettres* (1988), II. 123–45.

6 He had proposed doing the same for the *Discours de la méthode*, as he said in its sixth part: AT vi. 75–6.

7 Laurence W.B. Brockliss, *French Higher Education in the Seventeenth and Eighteenth Centuries* (Oxford, 1987), 345–50; Desmond M. Clarke, *Occult Powers and Hypotheses* (Oxford, 1989), 11–42. The charges that Cartesianism attacked accepted authority, sapped its efficacity by teaching students to be ignorant of its terms and so of its arguments, and shaped false and heretical ideas, went back to Voetius' attacks of the 1640s.

8 Jacques Rohault, *Rohault's System of Natural Philosophy, Illustrated with Dr. Samuel Clarke's Notes taken mostly out of S^r Isaac Newton's Philosophy*, with additions, trans. John Clarke, 2nd edn., 2 vols., (London, 1728–9, sig. A3^ro-B[8]^ro. Cf. Nicholas Jolley, 'The Reception of Descartes's Philosophy', in John Cottingham, ed, *The Cambridge Companion to Descartes* (Cambridge, 1992), 404.

9 Brockliss, *French Higher Education*, 350–9.

10 Nicolas-Joseph Poisson, *Commentaires ou remarques sur la méthode de René Descartes* (Vandosme, 1670), 78–9.

11 AT iii.185 (letter to Mersenne, 30 September 1640).

12 Poisson, *Commentaires,* 200.
13 Ernst Cassirer, *Das Erkenntnisproblem in der Philosophie und Wissenschaften der neueren Zeit,* 4 vols. (Berlin, 1906–57), i. 134–41, esp. 139; 'Galileo's Platonism', in M.F. Ashley Montagu, *Studies and Essays in the History of Science and Learning* (New York, 1944), 277–97.
14 Neal H. Gilbert, *Renaissance Concepts of Method* (New York, 1960); 'Galileo and the School of Padua', *Journal of the History of Philosophy* vol. 1 (1963), 223–31.
15 William F. Edwards, 'Randall on the Development of Scientific Method in the School of Padua – a Continuing Reappraisal', in John P. Anton, ed., *Naturalism and Historical Understanding* (Albany, 1967), 53–68: here 55–6. What immediately follows is largely drawn from this essay. Edwards has done much to refine and reinstate Randall's general claim: see, too, his 'Logic of Iacopo Zabarella', PhD dissertation, Columbia University, 1960; and the essays referenced in notes 19 and 39 below.
16 Edwards, ibid., 58–9. The reference is to *Plusquam commentum in parvam Galeni artem* . . . (Venice, 1557), f. 175vo. It is of interest that this lack of distinction between method as doctrinal knowledge and method as problem solving or discovery was crucial to a major Hellenistic debate: the Academic Carneades (214–129/8 BC) rejecting the Stoics' apparent division of the goal of life as the rational choice of things in accord with nature from that of virtue as the art (*techne*) of so choosing. Either, he said, this gave two separate goals, or goal and reference of action were distinct (for getting things, said the Stoics, could not itself be life's goal). Antipater (fl. c. 145 BC) replied by comparing an archer shooting at a target: the goal was not to hit the target but to do all one could to hit it. Doing the last, one took every step given by one's art to reach the goal, actually to reach it needed more. The good life, Antipater said, lay in the doing. The same held for 'the so-called stochastic crafts, like medicine, navigation, or rhetoric' (Gisela Striker, *Essays in Hellenistic Epistemology and Ethics* (Cambridge, 1996), 241–8: quotations 242–3). This applies to the Galen glosses in that a geometer was an archer analyzing target and ambient conditions and making a figure to show the arrow's path from bow to bull, a doctor was an archer partly knowing the analysis but having to *get* arrow to target, cure to body. Galen censured Stoic physiology, not their philosophy, and would surely favour the latter kind of method, not the geometers'.
17 Edwards, ibid., 63; Randall, 'Development', in *Renaissance Essays,* 225; Nicholas Jardine, 'Galileo's Road to Truth and the Demonstrative Regress', *Studies in History and Philosophy of Science* vol. 7 (1976), 277–318, here 286. Jardine's essay seems to me quite the best available analysis of *regressus.*
18 Some material of what immediately follows is taken from my *Knowledge, Discovery and Imagination in Early Modern Europe* (Cambridge, 1997), 150–1. This book analyzes the sixteenth-century path from language to mathematics in matters of discovery, and much of it is relevant to the present argument.
19 William F. Edwards, 'Niccolò Leoniceno and the Origins of Humanist Discussion of Method', in Edward P. Mahoney, ed., *Philosophy and Humanism* (Leiden, 1976), 283–305: here 292–3; Jardine, 'Galileo's Road', 286.
20 Edwards, 'Leoniceno', 296–9. The comments about Stoicism in note 16 above are apposite here as well.
21 Agostino Nifo, *Aristotelis physicarum acroasum . . . liber, interprete atque expositore E.A. Nypho* (Venice, 1508) 7vo col. 2–8ro col. 1, quoted by Jardine, 'Galileo's Road', 290: the bracketed interjections are Jardine's.
22 Jardine, ibid., 290–5.
23 See, for example, Reiss, *Knowledge,* 115–17.
24 William A. Wallace, *Galileo's Early Notebooks: The Physical Questions* (Notre Dame, 1977; *Prelude to Galileo* (Dordrecht, 1981); *Galileo and His Sources* (Princeton,

1984); *Galileo, the Jesuits and the Medieval Aristotle* (London, 1991); *Galileo's Logical Treatises* (Dordrecht, 1992); *Galileo's Logic of Discovery and Proof* (Dordrecht, 1992).

25 Domingo de Soto Segobiensis, *In Porphirii Isagogen, Aristotelis Categorias, librosque de Demonstratione, absolutissima commentaria* . . . (Venice, 1598), 3–5.

26 Vicente Muñoz Delgado, *Lógica formal y filosofía en Domingo de Soto (1494–1560),* (Madrid, 1964), 63–6.

27 Reiss, *Knowledge,* 95–6, 116–21.

28 Petrus Fonseca, *Institutionum dialecticarum libri octo* . . . (Coimbra, 1575), 1–9.

29 Franciscus Toletus, *Introductio in Dialecticam Aristotelis. Libri quinque* (Rome 1601), 3.

30 I refer here to analyses in chs 3 and 4 of my *Descartes, Philosophy and the Public Sphere* (in preparation).

31 'Porphyrii Phenecei introdvctio Severino Boetio interprete', Toletus, *Introductio,* 295–313.

32 Wallace, *Galileo's Logic of Discovery,* 15–16.

33 Reiss, *Knowledge,* passim.

34 'The *Ratio Studiorum* of 1599', trans. A.R. Ball, in Edward A. Fitzpatrick, ed., *Saint Ignatius and the Ratio Studiorum* (New York, 1933), 169: 'Rules for the Professor of Philosophy', 9.1.

35 Franciscus Toletus, *Commentaria, unà cum quaestionibus, in universam Aristotelis logicam* (Cologne, 1596), 1.

36 Toletus, ibid., 2–7.

37 Aristotle, *Prior Analytics,* trans. A.J. Jenkinson, in *The Complete Works,* rev. Oxford trans., ed. Jonathan Barnes, 2 vols., 1.73 (46c3–18).

38 *Topics* 1.168 (101b3–4).

39 Edwards, 'Paduan Aristotelianism and the Origins of Modern Theories of Method', in Luigi Olivieri, ed., *Aristotelismo veneto e scienza moderna: Atti del 25º anno accademico del Centro per la storia della tradizione aristotelica nel Veneto,* 2 vols (Padua, 1983), i. 206–20: here 208.

40 Paul Oskar Kristeller, *La tradizione aristotelica nel rinascimento* (Padua, 1962), 23.

41 Heikki Mikkeli, *An Aristotelian Response to Renaissance Humanism: Jacopo Zabarella on the Nature of Arts and Sciences* (Helsinki, 1992), 46–7. This work, Edwards' *Logic* and Antonino Poppi's *Introduzione all'aristotelismo padovano* (Padua, 1970), and *La dottrina della scienza in Giacomo Zabarella* (Padua, 1972), are basic on Zabarella. See too Jardine, 'Galileo's Road', 296–304; Giovanni Papuli, 'La teoria del *Regressus* come metodo scientifico negli autori della scuola di Padova', in *Aristotelismo Veneto e scienza moderna,* 221–77; Wilhelm Risse, 'La dottrina del metodi di Zabarella', in ibid., 173–86; and Wallace, *Galileo, the Jesuits,* 129–59, and *Prelude,* II and V. But all work on Renaissance Aristotelianism and method treats Zabarella. I have also used Stephen Gaukroger, *Explanatory Structures: A Study of Concepts of Explanation in Early Physics and Philosophy* (Atlantic Highlands, NJ, 1978), 167–9, and Lisa Jardine, *Francis Bacon: Discovery and the Art of Discourse* (Cambridge, 1974), 54–8.

42 Jacopo Zabarella, *De natura logicae, libri duo,* in *Opera logica,* praef. Joannis Ludovici Havvenrevteri, (Frankfurt, 1608), col. 21.

43 Zabarella, *De natura logicae,* col. 27.

44 Jacopo Zabarella, *Liber de regressu,* in *Opera logica,* col. 481.

45 Mikkeli, *An Aristotelian Response,* 59.

46 Aristotle, *Topics I, Complete Works,* 1.175 (105a16–19).

47 *De regressu,* col. 481.

48 Wallace, *Galileo's Logic,* 21, 24, 57–8; *Galileo, the Jesuits,* 135–44.

49 Antonius Rubius, *Logica Mexicana siue commentarii in vniversam Aristotelis logicam* . . ., 2 parts (Cologne, 1605), Pt. II. col. 35.

50 Patricia Reif, 'The Textbook Tradition in Natural Philosophy, 1600–1650', *Journal of the History of Ideas* vol. 30 (1969): 17–32, here 21.
51 Jardine, 'Galileo's Road', 295–6; Antonio Pérez-Ramos, *Francis Bacon's Idea of Science and the Maker's Knowledge Tradition* (Oxford, 1988), 225.
52 Jardine, 'Galileo's Road', 301–3; Harold Skulsky, 'Paduan epistemology and the doctrine of the One Mind', *Journal of the History of Philosophy* vol. 6 (1968), 341–61, here 354–61. The complex ramifications of this 'mental world' are explored in detail in my *Aspects of Personhood in Ancient and Medieval Europe* and *Mirages of the Self: Patterns of Personhood in Early Modern Europe* (forthcoming).
53 Timothy J. Reiss, *The Discourse of Modernism*, Ithaca: Cornell University Press, 1982, 201–6.
54 Peter Dear, *Discipline and Experience* (Chicago, 1995), 47–57: quotation on 56. The references are to Scheiner's *Oculus* (1619) and Blancanus' *Sphaera mundi* (1620).
55 Jardine, 'Galileo's Road', 304.
56 The first citation is from Cesare Vasoli, 'Introduction', in Jacobi Zabarellae, *De methodis libri quatuor; Liber de regressu*, ed. Cesare Vasoli (Bologna, 1985), xi-xxviii: here xxi. The second is from N. Jardine, 'Epistemology of the Sciences', in Charles B. Schmitt, Quentin Skinner et al., eds., *The Cambridge History of Renaissance Philosophy* (Cambridge, 1988), 687–711: here 690.
57 Mikkeli, *Aristotelian Response*, 174–6.
58 This, again, is discussed in my *Descartes, Philosophy and the Public Sphere*, esp. chs. 4 and 8.
59 Wallace, *Prelude to Galileo*, 226.
60 AT vii. 155–6; ixA. 121–2.
61 AT vii. 156; ixA. 122.
62 AT vii. 155.
63 Garber concludes his 'J.B. Morin and the Second Objections' (see note 3 above), by asserting that 'the doctrine of analysis and synthesis' was not 'a central tenet in Descartes' own thought' (82). I'm not sure what this means, but I do of course argue that the debates to which this 'tenet' referred were essential to the *development* of Descartes' thought and that conclusions drawn from them, changing their sense of synthesis and analysis, were indeed at the heart of Descartes' method. The present essay was not meant to confront others' views and I only came on Garber's essay after most of my discussion had long been elaborated. I may, though, have been influenced by his earlier piece: 'Descartes, the Aristotelians, and the Revolution that did not happen in 1637', *Monist* vol. 71 (1988), 471–86, as by his important book, *Descartes' Metaphysical Physics* (Chicago, 1992).
64 AT x. 376–9, 373, 454–69. In his *Descartes: An Intellectual Biography* (Oxford, 1995), Gaukroger analyzes these passages to show Descartes' intellectual development (99–101), to make an argument that in urging analysis he was advocating 'a problem-solving approach as the method of discovery' versus synthesis as a 'sterile' exercise in Aristotelian deduction (124–6: accurate but simplifying the issues) and to explain the algebra/analysis connection (174–6). These parts of Rule 4 are usefully annotated by Jean-Luc Marion in his edition, *Règles utiles et claires pour la direction de l'esprit en la recherche de la vérité* (The Hague, 1977), 137–52.
65 AT vi. 376 (*Géométrie*). See Dear, *Discipline*, 121–2.
66 Francis Bacon, *The Works*, ed. James Spedding, Robert Leslie Ellis and Douglas Denon Heath, 15 vols. (Boston, 1861–4), v. 359–413: here 412. See, too, my *Discourse of Modernism*, 190–1.
67 AT vi. 63–4.
68 For these references: AT x. 217, 373, and AT i. 145 (letter of 15 April 1630).

69 AT vii. 40, 42 (Meditation III), 53–4, 59–60 (Meditation IV).
70 AT vii. 192 (Third Objections and Replies).
71 AT vi. 76.
72 AT i. 410–11 (letter of 3 October 1637).
73 '*Magnitudines autem, figurae, situs & motus pro meo obiecto* formali *(vt Philosophorum terminis vtar), & res physicae, quas explico, pro materiali sumendae sunt. At principia siue premissae, ex quibus conclusiones istas deduco, sunt tantum illa axiomata quibus Geometrarum demonstrationes nituntur: vt,* totum est maius sua parte; si ab aequalibus aequalia demas, reliqua erunt aequalia; &c. *non tamen ab omni sensibili materia abstracta, vt apud Geometras, sed varijs experimentis sensu cognitis atque indubitatis applicata; vt cum ex eo quod particulae salis sint oblongae & inflexiles, deduxi figuram quadratam eius micarum, & alia quam plurima, quae sensu manifesta sunt: haec quidem per illud volui explicare vt effectus per causam; nequaquam autem probare, quia iam erant satis nota, sed contra illud per haec* à posteriori *demonstrare . . .*' AT i. 476 (letter of 20 December 1637). The opening of *Le Monde*, analyzing observed flame as made of particles in motion, was an unsatisfactory version of the technique: see Timothy J. Reiss, 'The *concevoir* Motif in Descartes', in J. van Baelen and D.L. Rubin, eds., *La cohérence intérieure* (Paris, 1977), 203–22.
74 AT vii. 537–9 (letter of 22 February 1638).
75 AT ii. 197–8.
76 AT ii. 199.
77 Jardine, 'Galileo's Road', 313 n86.
78 See also Desmond M. Clarke, 'Descartes' Philosophy of Science and the Scientific Revolution', in *The Cambridge Companion to Descartes*, 258–85: here 274–6.
79 AT vii. 156–7; ixA. 122.
80 AT vi. 2.
81 AT vi. 2, 10.
82 AT vi. 17.
83 AT vi. 18–19.
84 '*Premierement, i'ay tasché de trouuer en general les Principes, ou Premieres Causes, de tout ce qui est, ou qui peut estre, dans le monde,sans rien considerer, pour cet effect, que Dieu seul, qui l'a creé, ny les tirer d'ailleurs que de certaines semences de Veritez qui sont naturellement en nos ames. Aprés cela, j'ay examiné quels estoient les premiers & plus ordinaires effets qu'on pouuoit deduire de ces causes: et il me semble que, par la, i'ay trouué des Cieux, des Astres, vne Terre, et mesme, sur la terre, de l'Eau, de l'Air, du Feu, des Mineraux, & quelques autres telles choses, qui sont les plus communes de toutes & les plus simples, & par consequent les plus aysées a connoistre. Puis, lorsque i'ay voulu descendre a celles qui estoient plus particulieres, il s'en est tant presenté a moy de diuerses, que ie n'ay pas creu qu'il fust possible a l'esprit humain de distinguer les Formes ou Especes de cors qui sont sur la terre d'vne infinité d'autres qui pourroient y estre, si c'eust esté le vouloir de Dieu de les y mettre, ny, par consequent, de les rapporter a nostre vsage, si ce n'est qu'on viene au deuant des causes par les effets, & qu'on se serue de plusieurs experiences particulieres. En suite de quoy, repassant mon esprit sur tous les obiets qui s'estoient iamais presentez a mes sens, i'ose bien dire que ie n'y ai remarqué aucune chose que ie ne peusse assez commodement expliquer par les Principes que i'avais trouuez.*' (AT vi. 63–4).
85 '*Mais il faut aussy que i'auouë, que la puissance de la Nature est si ample & si vaste, & que ces Principes sont si simples & si generaux, que ie ne remarque quasi plus aucun effect particulier, que d'abord ie ne connoisse qu'il peut en estrededuit en plusieurs diuerses façons, & que ma plus grande difficulté est d'ordinaire de trouuer en laquelle de ces façons il en depend. Car a cela ie ne sçay point d'autre expedient, que de chercher derechef quelques experiences, qui soient telles, que leur euenement ne soit pas le mesme, si c'est en l'vne de ces façons qu'on doit l'expliquer, que si c'est en l'autre*'. (AT vi. 64–5).

86 AT i. 476.
87 AT ii. 157–9.
88 AT vi. 76.
89 AT vi. 83.
90 AT vi. 81.
91 '*portant nostre veüe beaucoup plus loin que n'auoit coustume d'aller l'imagination de nos peres, elles semblent nous avoir ouuert le chemin, pour paruenir a vne connoissance de la Nature beaucoup plus grande & plus parfaite qu'ils ne l'ont eue*'.
92 On this, see Reiss, *Discourse*, 25, 31; 'Espaces de la pensée discursive: le cas Galilée et la science classique', *Revue de Synthèse* vol. 85–6 (1977): 5–47; and ch. 6 of *Against Autonomy: Cultural Instruments, Mutualities and the Fictive Imagination*, forthcoming.
93 AT vi. 62.

10 Figuring things out

Figurate problem-solving in the early Descartes

Dennis L. Sepper

It is hardly surprising to see figures when one opens mathematics or physics texts. All but the most abstract approaches to the most abstruse mathematical and physical sciences include illustrations, figures, and graphs. Nor is it surprising to find diagrams where a text shows how to solve problems. We do, after all, think of ourselves as figuring out mathematics and science problems.

From the perspective of this expectation it should not be surprising that we find figures in Descartes' writings, not least because he is one of the co-inventors of analytic geometry, a discipline that teaches us how to graph equations, to present them visually, in figures.

To be the inventor of analytic geometry Descartes had to innovate in some way. It is traditional to emphasize his innovations in symbolism and in the expression of geometrical relations by means of algebraic equations. More historically accurate would be to say that they involved a protracted investigation of proportions and proportional relations, and that in effect his algebra is a formalisation of extended, complex proportional relations.[1] Moreover, this algebra was initially intended as a shorthand representation of the concrete, visualisable relations of geometric figures. That is, the truth of Descartes' mathematics is more or less the reverse of the traditional accounts.

To be sure, there has been no lack of scholars who have pointed out the primacy of geometry in Descartes' mathematics, a primacy that seems odd for an inventor of a systematic, powerful, modern algebra. In this chapter I shall argue, however, that Descartes' commitment to geometry is a concomitant of his basic approach to mathematics and physics: problem-solving based on the concrete figuration of problems.

Preliminaries

Looked at from a perspective several centuries after the fact, Descartes' mathematical techniques seem intermediate between what preceded him and what came after. Along with his contemporary Pierre Fermat, Descartes is credited with inventing analytic geometry, which is based on the fundamental notion that algebraic equations determine points, lines, and surfaces when they are plotted onto a system of coordinates. In a system of mutually perpendicular linear coordinates, known of course as Cartesian coordinates, the two-dimensional representation of $x^2 + y^2 = 4$ is a circle of radius 2 around the point of origin (0,0); in three-dimensional space the same equation determines a cylinder of that radius centred on the point of origin (0,0,0) and extending infinitely along the z-axis in both directions. Descartes did not use Cartesian coordinates; however, he did develop a technique whereby lines given as part of the problem were in effect used as coordinate axes (thus they ordinarily were not perpendicular to one another), with all other points determined by their distance from these lines. He furthermore showed how algebraic equations determined figures in space, and how from both static and moving geometric situations one could derive algebraic equations. Not the least of his achievements herein was the symbolism he employed in forming and manipulating algebraic equations; it is essentially our own and greatly facilitates problem-solving.

Nevertheless, Descartes' techniques can strike us as rather archaic. Descartes' *Géométrie* (1637) in effect remains within the ambit of geometry, since he employs the analytic techniques of algebra in order to construct solutions to geometrical problems that had been beyond the capacity of ancient geometers. Up to Descartes' day, geometry was the queen of the mathematical sciences; arithmetic was a junior partner or ancilla in comparison, and generalised techniques of treating numbers and equations symbolically – what we know as algebra – only began emerging in the sixteenth century.

A key limit to the ancient mathematicians' ability to solve problems was the geometrical interpretation of arithmetical operations. Adding two to three was understood as the joining together of a line segment two units long and another of length three. Adding two line segments produced another line segment. Multiplication, on the other hand, required constructing a rectangle out of the two line segments standing for the numbers; thus 2×3 was interpreted as the area of the rectangle with sides two units and three units. Squaring a number like 3 was literally interpreted as producing the square with side-length 3. Multiplying three numbers together resulted in a three-dimensional solid whose volume was the product desired. Multiplying four numbers was strictly speaking impossible, although already in Hellenistic antiquity some mathematicians approached the issue as one of extended proportion (which to us is equivalent to dealing in equations and operations requiring powers and spatial dimensions higher than three).

As we shall see below, in his early writings Descartes continued the ancient practice of correlating numbers and figures, and that even in physical problems he tried to represent in a figurate form all kinds of factors that we would treat algebraically. As for the problem of multiplying numbers, already in the *Regulae ad directionem ingenii* (abandoned in incomplete form c. 1629) he proposed a technique of reducing numbers expressed as areas to linear form (as well as the easier one of raising linear numbers to two dimensions); but in the *Géométrie* he offered a technique that did not require dealing with areas but only with curved and straight lines. The ancient problem of multiplying together four numbers thus vanished, because multiplying line lengths always produced just a new line length.

Descartes' figurations

How did Descartes use figures in solving mathematical and physical problems? Let us take a brief look at several examples.

In the *Compendium musicae*, which he presented as a New Year's gift to Isaac Beeckman in 1619, Descartes employed lines, charts, and annotated circles to display graphically the relationships of musical tones. One of the simplest figures is emblematic of how Descartes used them. A line segment AB (see Figure 10.1)[2] is bisected at C; the half to the right of C is bisected at D; the quarter to the right of C is bisected at E; the eighth to the right of C is bisected at F. If AB were the string of an instrument, stopping it at C (and sounding AC) would yield a tone an octave above the tone of the full string. Furthermore, the relation between AC and AD is a major fifth; between AD and AB a major fourth; between AC and AE a major third. All the relationships involving the last division at F, however, produce dissonances. The divisions that lead to consonances can be expressed by fractions, that is, proportions, using just the integers 1, 2, 3, 4, and 5. What the figure does, then, is, first, represent possible stoppings of a real string; second, it expresses visually and by division some of the fundamental relationships of consonance and dissonance; third, it perspicuously embodies simple numerical relationships that can be expressed as proportions. The figure is simple, it is economical in its embodiment of musical relationships, and it displays them to the eye and the mind's eye simultaneously.

A more complicated case of Descartes' figuration can be found in an entry of Beeckman's *Journal* nearly a decade later, a so-called 'specimen of Descartes' algebra' recorded as a result of an encounter between the two men in October 1628. Descartes showed Beeckman how to solve the equation $x^2 = 6x + 7$. Our contemporary techniques for solving it are quite straightforward and easy. Knowing the general formula for the two solutions to a quadratic equation, $x = (-b \pm \sqrt{b^2 - 4ac})/2a$, where the equation is of the form $ax^2 + bx + c = 0$, if we rewrite Descartes' equation as $x^2 - 6x - 7 = 0$ we can quickly ascertain the two solutions for x, 7 and -1.

Figure 10.1

Alternatively, if we recognize that the equation can be factored as $(x - 7)(x + 1) = 0$, we can rapidly infer the same solutions.

A more old-fashioned way brings us closer to Descartes' technique. If we add or subtract the same quantity on both sides of the equal sign, so that the left-hand side of the equation can be expressed as a perfect square, we can easily infer the solution. In general, for a quadratic equation of the form $x^2 + bx + c = 0$, this can be done by halving the coefficient of the term in x (to get $b/2$), squaring it (giving $b^2/4$), subtracting from it the third term, c ($b^2/4 - c$), and then adding this amount to both sides of the equation.[3] In Descartes' equation b is -6 and c is -7, so $b^2/4 - c$ is $9 - (-7) = 16$, which when added to both sides yields $x^2 - 6x + 9 = 16$, or, expressing the left-hand side as a square, $(x - 3)^2 = 16$. This means that $x - 3 = \pm 4$, from which we conclude once again that $x = 7$ or -1.

This latter technique of seeking squares is old, almost as old as attempts to solve quadratics; it is literally based on the use of geometric squares, and it is how Descartes proceeds to work the problem. According to Beeckman's account (although using our modern symbolism rather than cossic symbols[4]), Descartes proposed solving $x^2 = 6x + 7$ as follows:

> In this method, the same man [i.e. Descartes] reduces a binomial to one term, as you see. In fact, wishing to take away 6 roots of the unknown square *ab* [see Figure 10.2], he divides 6 by 2. But, because both *fc* and *gb* contain 3 roots, the square *dc* is taken away twice when *fc* and *gb* are removed; accordingly, $6x$ and a square of the half, i.e. 9,

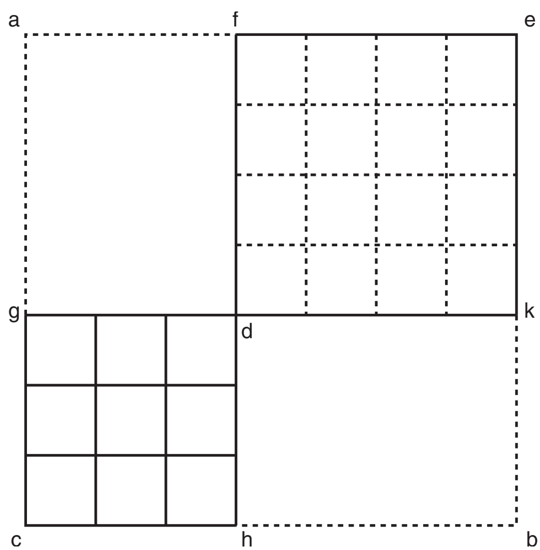


Figure 10.2

> will be taken away. Therefore, one who wants to remove $6x$ must add 9 so that the lesser square *de* may remain. Once this has been known, its side is also known, since the half of the root being added, the root of the first square is obtained. Thus the lesser square is taken out from the larger, through which the larger root is found.[5]

Reformulating Beeckman's account in a series of three steps, Descartes' strategy is (1) to represent the as yet unknown area x^2 by a square (*aebc*, named by Beeckman using just two, diagonally opposed letters, *ab*); (2) to use the equation, the setting equal, of x^2 with $6x + 7$ as a guide to finding a way to remove segments of the square *ab* in order to determine a specific smaller square (*de*) within *ab*; and, finally, (3) to exploit the resulting algebraic and geometrical relations to derive a value for x.

Here is, according to Beeckman, how Descartes proceeded in detail:

1 In accordance with the tradition of interpreting arithmetic and algebraic relations geometrically, Descartes stipulates that *ab* (*aebc*) is a square, with each side of length x; its area thus equals x^2.

2 For the next step, he is guided by the same consideration that we used to solve the equation by the perfect square method: take the coefficient 6 of the x-term and halve it to get 3. But we were concerned to subtract or add equal numbers on both sides of an equation; Descartes on the other hand is trying to determine what rectangles to subtract from the square *ab* so that he will end up with a smaller, 'solvable' square. Since each side of the square *ab* is x in length, he imagines that three unit lengths (the result of dividing 6 by 2) are marked off from *c* toward *b* and again from *c* toward *a*.[6] If we focus for a moment on the rectangles *fc* (*afdhcg*) and *gb* (*cgdkbh*), we see that if we remove them from the large square we will be left with the smaller square *de* (*dfek*). Actually we will be removing too much, since the rectangles have the square area *cd* (*cgdh*) in common; we will have removed this 3 unit by 3 unit square twice. Taking away both rectangles *fc* and *gb* removes too much area, then, but we can compensate by adding back 9 units of area, that is, the area of one 3 by 3 square. Therefore we can conclude that the area of the smaller square *de* is equal to the area of the larger square *ab* minus *fc* minus *gb* plus 9.

3 Now notice that each of the subtracted rectangles *fc* and *gb* measures x units long by 3 units wide, and so each has area $3x$. From Descartes' original stipulation, *ab* equals x^2; so since the original equation stipulated that $x^2 = 6x + 7$, the area of square *ab* must equal $6x + 7$. Repeating the assertion of the previous paragraph's last sentence, but now noting several substitutions of equals for equals: the smaller square *de* is equal to *ce* ($6x + 7$) minus *fc* ($3x$) minus *gb* ($3x$) plus 9; that is, the area of *de* is $(6x + 7) - 3x - 3x + 9$, which means the area of *de* equals 16. But then square *de* must be 4 units on a side. Since

line $df = ag$, ag is also 4, and then since $x = ag + gc$ and $gc = 3$, we can conclude that x must be $4 + 3 = 7$.

By a rather convoluted process of correlating geometry with algebra and working from both the equation and the geometrical figure, we have reproduced Descartes' path to the positive root of the original equation. Of course the other, negative root, -1, cannot have any meaning here, given that all line lengths and areas we can draw must represent positive numbers. Moreover, the specific problem proposed had a relatively easy, whole-number solution because of the original equation. Nevertheless, the process can be applied to other equations of the same type (for example, any equation $x^2 = bx + c$, where b and c are positive integers or even fractions), although the answer will not in general be a whole number.

Of course, the approach that we have followed here does not represent the full sophistication of Descartes' mathematics as of October 1628. It is likely that already a decade earlier (c. 1619–20) he could have solved the problem in this way; and he might have applied more efficient techniques utilizing the various proportional compasses he had conceived.[7] Moreover, between 1619 and 1628 he also worked out far more sophisticated techniques by employing conic section curves (which correspond to equations of the second degree) in order to solve equations of degrees three and four.[8] Yet in most important respects these alternative techniques would only reinforce the impression made by the example at hand. In algebra Descartes was intent on a methodical use of geometrical figures to solve problems. He proceeds by specifying the correlations between the algebraic elements and the geometrical figure as precisely and systematically as possible; and he uses techniques that work not just for the problem at hand but for all problems of a type. This is his general approach to solving mathematics and physics problems from 1619 onwards.

This is even clearer from the mathematical-physical problems he recorded in a notebook kept during the period 1619–21, parts of which were copied for Leibniz and ultimately published in the mid-nineteenth century under the title *Cogitationes privatae*. Let us examine just one, a problem much studied in the Descartes literature, the falling body problem posed by Beeckman.[9] The question is: if a body falls from A to B in one hour, and the earth's attraction is uniform and constantly increases the speed of the body, how is the space (or distance) traversed related to the time? We know from Beeckman's *Journal* that what he actually asked was how far the stone would fall in one hour (given the uniform increase in speed due to the earth's attraction), if we knew how far it fell in two. As is customary for him, Descartes took the more general approach, to a problem type, and characteristically he gave the various factors an integrated, figurate representation.

Descartes believed that the solution could be derived from an analysis

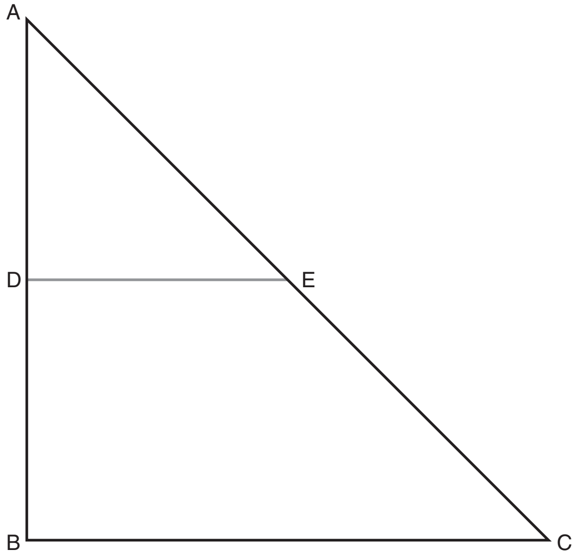


Figure 10.3

of a triangle used to represent the situation (see Figure 10.3). He interpreted lengths along the vertical side AB as standing for the distance traversed, and the areas of the corresponding triangles and trapezoids produced by drawing parallels to the base BC as representing the inverse of the time elapsed during that fall (greater areas mean shorter times). Thus, from A to D the time of fall is proportional to 1 divided by the area ADE, the time of fall from A to B is proportional to 1 over ABC, and the fall from D to B to 1 over DBCE. Descartes' conclusion from a comparison of the areas was that, assuming that D is the midpoint of AB, the stone takes three times as long to traverse AD as it does to traverse DB (since the area of triangle ADE is one-third the area of trapezoid DBCE). The solution to Beeckman's question about the relation between one-hour and two-hour falls is thus implicitly solved.

By means of the figure Descartes tried to correlate in an exact fashion the distance traversed (along AB), the additions of speed produced by the earth's attractive force (indexed by the increasing lengths of the horizontal segments like DE), and the elapsed time (represented by the inverse of the areas). Moreover, he applied further figures to the original triangle in order to arrive at his answer in a more exacting way. The smaller triangles along the hypotenuse in Figure 10.4 represent how Descartes analyzed the increasing speed of fall by dividing the path into smaller and smaller parts and treating the earth's force of attraction as though it acted in a series of discrete impulses, each adding a new small increment to the speed already attained. In essence this translates the continuous force of attraction into a series of discrete attraction-impulses; as the fall is divided into ever

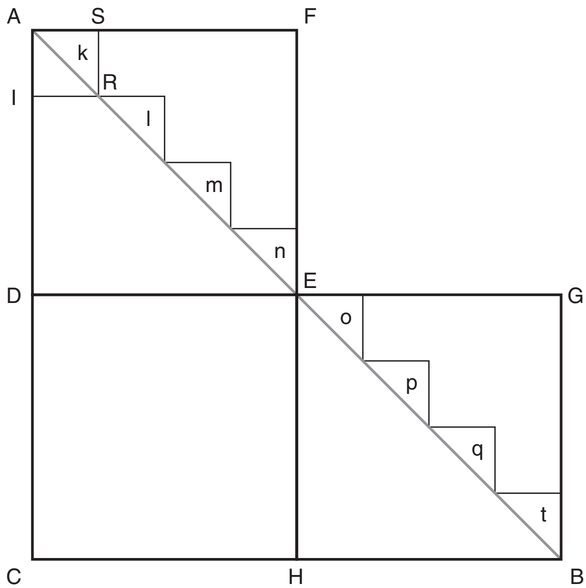


Figure 10.4

smaller parts, the discrete impulses approach ever more closely the situation of continuous force.

It is not important here to emphasise that Descartes' analysis was physically wrong – he failed to arrive at the correct, Galilean law of fall – and that instead it was Beeckman who provided the correct interpretation (in which the distances along AD measure time elapsed rather than distance traversed, and the areas of the triangles and trapezoids represent the distance rather than the time). The important point is that, although Descartes' own assignment of problem factors to the parts of the triangle was faulty, the very same figure could be used with a different assignment to yield the right answer. The virtue of the technique of figurate analysis is that it is thoroughgoing, it demands a consistent interpretation of the factors involved, and it offers concrete visual aids to the problem-solver. A figure embodies not just the solution to the particular problem but also to innumerable variants. So, for example, AD and AB in Figure 10.3 can represent three minutes and six minutes as easily as one and two hours, and the figure as a whole implicitly answers questions about relationships of speed, distance, and time of fall for all possible combinations of these factors. This method of figuring problems out, understood quite literally as a process of figuration, was key to the new method and mathematics that Descartes developed around the year 1620.

This is not at all to argue that Descartes was the first to use figures to address physical problems, but he was one of the very first to try to exploit them intensively and systematically. Once we are aware of how deeply intertwined in his method are problem-solving and the search for appropriate figuration, the more obvious it becomes that this is at the heart of his mathematical and physical work from very early on in his career. A further survey of the *Cogitationes privatae* would show that he was not so much concerned with exact solutions to specific problems, as he was with identifying the kinds of curves, figures, and solids required for solving problems of a given type, and with how these figures could be varied and manipulated to produce and reveal further relationships. In the *Cogitationes privatae* Descartes began to imagine new uses for the traditional compass of Euclidean geometry and conceive new devices for constructing more complex curves than the Greeks had been capable of.[10] For example, he imagined a traditional, two-legged compass to be provided with an infinitely telescopable leg bearing a pencil, so that if the other leg were held at a fixed oblique angle to a given plane, the pencil would trace out on the plane (e.g. on a pad of paper) a noncircular conic section (i.e. an ellipse, parabola, or hyperbola, depending on the angle of the fixed leg to the plane).[11] He conceived of more complex instruments that could be adjusted to correspond to the specific givens of geometry and algebra problems and that, employed dynamically, could be operated to generate curves corresponding to algebraic equations of higher powers than quadratic equations (i.e. of powers higher than two). In Figure 10.5 is pictured

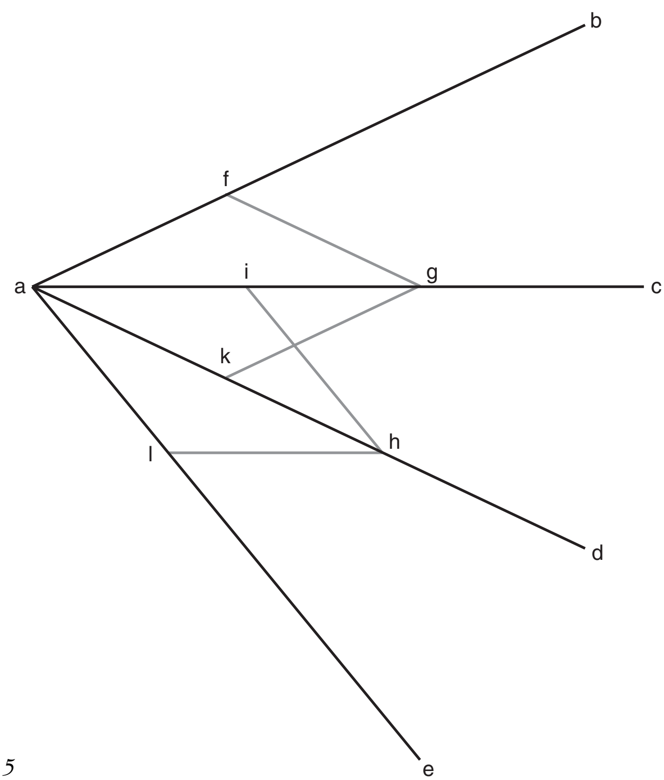


Figure 10.5

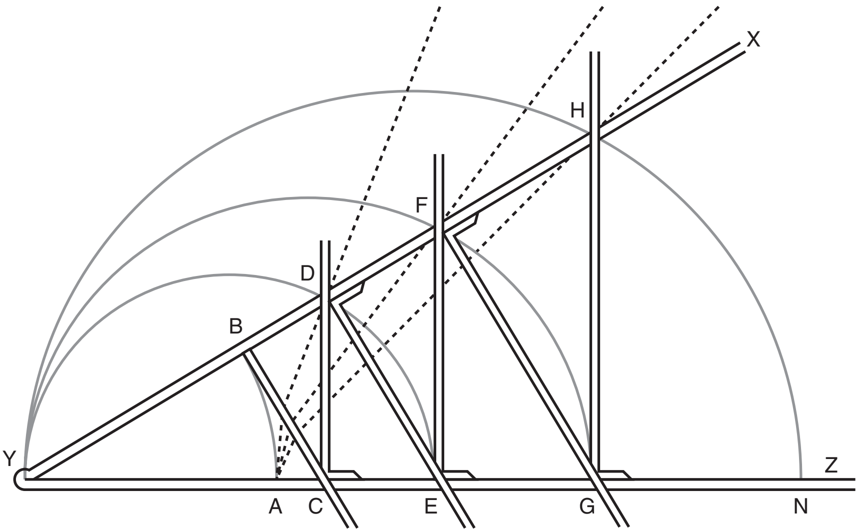


Figure 10.6

a device to trisect any angle; the device of Figure 10.6 is meant to determine any number of mean proportionals between two arbitrarily given line lengths.[12] In both cases the device consists of a network of rulers, some of fixed length but most indefinitely extendable; the rulers in the network are connected by pivot points and/or grooves, so that as the instrument is opened or closed some rulers only rotate, some only slide, and others both slide and rotate. By these interlinkages the various parts maintain certain basic relations to one another throughout all the movements (e.g. some parts remain perpendicular to one another, and there is maintained a fixed proportion between the lengths of different rulers). Moreover, if one could attach pencils to the changing points of intersection of the rulers, they would trace out curves corresponding to higher order algebraic equations (with coefficients determined by the originally given ruler lengths).[13]

This is but a small sampling of Descartes' early use of figures. By the middle 1620s he had become quite adept in devising and using figures to solve problems; he could be conservative (as in the 1628 solution of $x^2 = 6x + y$) or quite innovative (as in the devices of the *Cogitationes privatae*). Indeed, he does not seem to have developed a single, unified methodology as of October 1628, when he provided Beeckman with a specimen of his algebra; rather, he was willing to use any determinate technique whatsoever, so long as it contributed to a solution.[14] By the early to middle 1630s, however, he would arrive at a much more standardised process that is recorded in the *Géométrie* of 1637. We will not follow the development so far. However, we are now sufficiently prepared to see how

Descartes articulated a philosophical method of problem-solving corresponding to his techniques of figuration, a philosophical method contemporaneous with these examples.

The theory of figuration in the *Regulae ad directionem ingenii*

Why does the early Descartes use figures as he does? One of the few explicit discussions of this question occurs in the *Regulae ad directionem ingenii*. The first place he does this is near the outset of Rule 12, where he considers how the sense organs are affected by sights, sounds, odours, and smells. Adapting to his purposes the well-worn Aristotelian analogy of sense perception to the impression of a seal in wax,[15] Descartes argues that impression is no mere analogy but what literally happens. He claims that in sensation it is

> simply to be conceived that the external figure of the sensing organ is really changed by the object in the same way that the figure in the surface of the wax is changed by the seal. . . . Thus does the first opaque membrane in the eye receive the figure impressed by the light endowed with various colours; and the first skin of the ears, nostrils, and tongue that is impervious to the object likewise also takes on a new figure from sound, odour, and flavour.[16]

Thus in sensation there takes place a natural process of figure making. It is Descartes' intention to take this in a much more literal sense than does Aristotle, for whom the sense organ is activated by the sensible form of the perceived object in a way that establishes a formal identity between the sensation and the object. The Aristotelian identity of the form of colour in the visible object with the form of colour in vision is translated by Descartes into the impression of a geometric form that is different from, but also a principal cause of, what we actually see. And, as Descartes' explanation of the process of sensation continues, this form is conveyed according to the same model of impression to organs in the brain, the common sense and the *phantasia* (or imagination), where, finally, the form can be impressed in the spiritual power, which in turn can impress forms in the imagination, although at this level the model is to be taken 'only by analogy' rather than literally.[17]

The point is not that Descartes here has achieved, or is on the verge of achieving, a primary/secondary qualities distinction, but rather that sensation operates by a kind of natural geometry: a surface pattern or form that is in the object is impressed on a membrane surface of the sense organ, which is then conveyed by nerves to higher organs in the hierarchy of sensation, until finally it reaches the spiritual or intellectual power. Already in 1618 Descartes had expressed thoughts along these lines. In the postulates prefaced to the *Compendium musicae* he claimed that the senses are designed to perceive simple proportions most easily of all, and that the pleasure in music is due to the artfully arranged variation of these sense proportions, both simple and complex.[18]

One of the points Descartes is making is that proportions are transferable from medium to medium, for example, from musical string to the ear, or from coloured object to the retina. This is explicated in Rule 12. Precisely after introducing the notion of the figure impressed in the first opaque membrane of the sense organ, Descartes provides a schema of three figures to represent the colours white, blue, and red (see Figure 10.7). He says not that these are the figures impressed but rather that some figures are impressed, and asks what inconvenience would follow if we would abstract from every other character of colour the fact of having 'the nature of figure', and 'conceive the diversity between white, blue, red, etc., just like the diversity between these or similar figures?'[19] The same sort of translation into figures could be done for all other senses, 'since it is certain that the infinite multitude of figures suffices to express all the differences of sensible things'.

Thus in Rule 12 we are told that what physiologically travels inward through the sense organs to the mind is figurate, and that the differences between things perceived can be expressed or at least represented by differences in figure. What is not said, but what Descartes certainly believed at this juncture, is that some day we may discover the true figures that are impressed in sense; but, lacking that knowledge, we can still figurately represent all such differences. The infinite variety of geometrical figures is more than capable of representing the proportionate relations that hold between the things of the world, and between them and our perception of them. Descartes' investigation of proportions by means of geometrical instantiation was therefore not a peculiarity of his mathematics or his symbolism, but intrinsic to his conception of the universe as embodying and transmitting proportions and proportional relations.

The task of Rule 12, as stated in its heading, is to teach us to make use of all aids to knowledge, in particular intellect, imagination, sense-perception, and memory. In the course of the rule we learn that memory

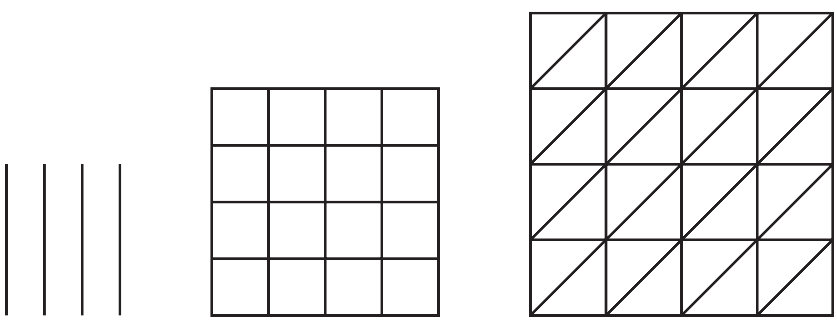


Figure 10.7

might be reduced to imagination and that sensation is the act of the intellect applying itself along with imagination to the common sense. What becomes clear, in the event, is that the figures and images presented to our minds come either actively through sense, through imaginative production, or through remembering, and that the mathematics of proportion can be comprehended autonomously by the cooperation of imagination with intellect.

In the later *Dioptrique* (1637) Descartes further developed the notion of a kind of natural geometry (and trigonometry) operating beneath the notice of consciousness (and thus, in accordance with his physiological theories, carried out by means of images conveyed by spirit flows in the nerves and brain). He speculated that the optical projection of two-dimensional figures onto our retinas produced lines, angles, and figures that the brain might use to determine object distances in three dimensions.[20] That is not the immediate direction in which the *Regulae* goes, although perhaps it is something ultimately intended. The immediately urgent question after Rule 12, however, is how to represent problems in figurate form in order to maximally facilitate their solution.

Rule 14 takes up in detail the question of how to maximize the efficient use of imagination, of image-making and manipulation, in problem solving:

> So that we might also, however, use the assistance of imagination, it is to be noted that insofar as one thing that was unknown is deduced from another already known before, no new genus of things is to be invented but rather this whole knowledge is only extended to our perceiving that the thing sought participates thus or so in the nature of those things that were given in the proposition [of the problem].[21]

In illustration, Descartes says that we cannot expect someone blind from birth to get a true idea of colours from arguments, no matter how compelling, but that if someone has seen at least the primary colours then 'he might make images also of those he has not seen from the similarity of others by means of some deduction'.[22] Likewise, if magnets and their effects involve some thing that the intellect has never before experienced and that is not similar to anything it has experienced, we will never be able to know it by reasoning, at least not until we acquire a new kind of sense organ or are divinely inspired. We are capable of perceiving and, in accordance with that perceiving, understanding, only familiar things or natures and their combinations. Our experience thus puts a limit to what and how we can understand, although our experience can be extended wherever we have a principle of proportion or analogy to lead us.

What Descartes counts on in this analysis is that what is given to us in experience, primarily in sense experience, must yield sufficient data for solving the problems we face. If we have to experience something that has not been experienced and cannot be, then we have no hope of a solution. But if we have the relevant experience, even if only the relevant elements of experience (like primary colours, out of which others might be formed), then a solution should be possible (unless something else stands in the way). He points out immediately that entities that are familiar to us, like extension, shape, and motion, are always recognized by the same idea in different things – the shape of the crown is the same whether it is silver or gold – and so 'the common idea is carried over from one subject to the other solely by means of a simple comparison, which enables us to state that the thing we are seeking is in this or that respect similar to, or identical with, or equal to, some given thing'.[23] In language that harks back to the first twelve Rules and that resumes a theme mentioned in Rule 6, Descartes asserts that all knowledge relies on comparison, and that comparison is based on the determination of whether two things participate equally or differently in a nature common to them.[24] Comparison is direct when the participation is equal, but more complicated and indirect when it is not. It is because knowledge is based on such comparisons that the figuration and proportionalisation of problems is possible; and it is because of the variety and expressivity of the infinity of available figures that there can be some arbitrariness in those chosen to represent a situation. As long as the figures and their parts express proportions in a determinate fashion, they can be used to solve problems.

Although figures are geometrical it is not the case that the *Regulae* is offering us a reaffirmation of the traditional primacy of geometry. At the end of Rule 14 Descartes says that the art of figuration is no different if we are trying to solve a geometry problem: there is nothing sacrosanct about the given figure, we will abstract from it just as much as from any other object of inquiry.[25] Indeed, what this signifies is that concentrating excessively on all the particularities of the kind of thing before our eyes and mind can impede understanding; what we need to do instead is to recast what is given into a form that makes perspicuous the relations that hold between the elements of the original problem. Figures of various kinds, but especially the simplest figures of all, are the best, because most perspicuous, way to represent these relations.

Order and measure are the chief desiderata of the *Regulae* and the fundamental principle of the method proposed there; and in fact measure is derivative from order (measure is an order in which one can specify a unit and then apply it in an orderly sequence to determine how many units the aggregate whole contains). The order and measure in problems derives from the fact that things participate in or contain natures to a determinate, and determinable, degree. These natures appear to us under the same idea (their typical appearance to sense or intellect), and this nature can be ordered or measured according to how much it participates in, is present in, the original objects of the problem situation we face; and if there is more than one kind of nature present, we can try to order or measure their interrelationships. To use a simple example, two squares of different size both exhibit the ideas or natures of spatiality or extension and of squareness (in this they are equal), but if one is twice as large as the other we measure the ratio of participation in the nature of planar area as 2:1; in turn, we can simply and perspicuously represent this ratio of areas by line segments, one twice the length of the other. If the nature of time were involved in the problem we could figure it similarly, using line segments or other simple figures to stand for the relationship of one time to others, and even of times to spaces (as in velocity or acceleration).

Because of this possibility of using simple figures to portray the elements and relationships of a problem situation – because of this *mathetical*[26] character of problems (and reality) – figures can be used to summarise and express the essential aspects of problems, and the character of the representation is dependent solely on what the problem states, implies, and seeks. Problem-solving is therefore not governed by a univocal and invariant theory but is always a matter of heuristics; what one does to represent and solve it is determined situationally, and the resources one deploys are whatever is needed or helpful. Insofar as the figures used embody information drawn from the givens, and determinately and precisely represent the relationships of the givens and the unknown, they can be manipulated according to a very basic mathematics. For Descartes in the *Regulae*, the most basic mathematics of all is founded in the expression of quantities as lines and rectangles; and as long as one has a technique of reducing rectangles to lines (that is, the number of the linear units in the line is equal to the number of square units in the rectangle) one never needs to go beyond the two dimensions of length and width. And therefore the impossibility of representing a fourth dimension that had bedeviled the ancients, or even rising to the third, never comes up.

The later parts of the *Regulae* were supposed to show how this mathematics works, beginning with elementary lessons about how to add, subtract, multiply, and divide quantities expressed in line lengths and how to use simple symbols to stand for and name the parts of the problem. In the history of mathematics this latter point, symbolisation rather than representative expression, is a major step toward analytic geometry, which allows us to present unknowns and knowns alike by using letter symbols, to solve for the unknowns by forming and manipulating equations by using basic operations of arithmetic, and to utilise graphic, that is, geometrical, representation of lines determined by the equations to help determine values of the unknowns that are the answers to our original question. Certainly, the *Regulae* took a major step along the way to this kind of graph-producing algebra of equations.

However, as has often been pointed out, Descartes' algebraic analysis tends to work in the other direction: his central purpose is to advance geometry, and the algebra he deploys is the ancilla. If my interpretation is correct, this is not an accident, and it does not have much to do with the traditional preeminence of geometry among the mathematical sciences. At least in the *Regulae*, and still to a surprising extent in the *Géométrie* (published 1637), the algebraic representation is subordinate, a memory aid to keep schematical track of the problem, its elements, and the process of solution that are actually presented and carried out through the geometric representation and manipulation of figures.

In Rule 16 Descartes explicitly states that the symbolic representation of lengths and areas is shorthand for aiding memory. Since comparison is clearest and easiest when only two things are involved, one needs some way to keep track of the things and relations one is not currently attending to. He even points out that it is important to keep track of all the parts of the problem being solved, so that instead of simply expressing the length of the hypotenuse of a triangle of sides 9 and 12 as the square root of the sum of their squares $\sqrt{9^2 + 12^2} = \sqrt{225} = 15$, we should rather use the formula $\sqrt{a^2 + b^2}$, which implies the numerical result, but also keeps distinct the distinct parts and reminds us of the generality of the process.

Much of what Descartes presents here is almost second nature to us, who are schooled in algebraic problem solving. In fact, that schooling would be likely to make us impatient of the punctiliousness with which Descartes coordinates figuration with symbolisation, and geometrical construction with equational manipulation. Suppose we were given a problem like this: two cities are 100 km apart; one truck proceeds steadily from the first to the second city at 20 km/h, while another proceeds from the second to the first at 40 km/h; the question is, where along the straight road connecting the cities do the trucks pass? We would probably start solving the problem by more or less following Descartes' advice: we would draw a line segment AB, the endpoints representing the two cities, and call it 100 units long; s_1 and s_2, the speeds of the trucks, we would mark down as 20 and 40, respectively. But we probably would not draw lines to represent s_1 and s_2. We might, after some thought and looking at the line AB, remark that at the point where the two trucks pass the sum of the distances covered by each truck will be 100 km (we might then mark a point X somewhere on AB to keep this in mind), and that at that moment both trucks will have been travelling for a length of time that we can call t. That is, we can write an equation: at time t, $s_1t + s_2t = 100$. Substituting numbers we get $20t + 40t = 100$ and discover, by performing the addition on the left side of the equation and then dividing both sides by 60, that $t = 5/3$ hours, and therefore that the point of crossing will be $33\frac{1}{3}$ km from one city and $66\frac{2}{3}$ km from the other. The techniques and power of algebra largely relieve us of the need to represent painstakingly all the factors geometrically. Yet it is only because we know that this representation can be done meaningfully and exactly that we can rely on the results of algebra, and insofar as any of the shortcuts we take are not clear to another person, we will need to correlate them carefully with the other figures and symbols we have used to solve the problem. To shift more decidedly into Descartes' way of thinking: every equation that we deduce from our original givens through addition, subtraction, multiplication, division, or root-taking is a guide to how we must geometrically manipulate the various original and derived line segments in order to derive new line lengths according to these operations.

Descartes' intention in the *Regulae* was not to teach shortcuts, but to show how knowing is different from opining, and how the interplay of native human abilities can be used to guarantee success in knowing. The mind does not need to know the essences of things, but rather the typical ways in which things appear and the relationships of these appearances to one another.[27] These relationships are due to the participation of 'natures' in one another; since participation varies in degree, and since some natures are invariably associated with others (as, for example, colours are always associated with some physical impression on the retina), this participation can be ordered, measured, and represented in an algebraic-geometrical way that is strictly and exactly perceivable and imaginable. When Rule 12 divides the natures into three kinds, the corporeal, the corporeal/spiritual, and the spiritual, we learn that the first two can always be instantiated, and therefore represented, in figurate form. And perhaps even the spiritual is susceptible to some kind of figurative representation, at least for the sake of problem solving: for if things such as willing and doubting are not imaginable per se, it is at least conceivable that certain acts of will are more intense than others, and that therefore their intensity could be ordered and even measured. It is possible, for example, that if one experiences certain volitions as much more intense than others, then some kind of measuring unit, or at least the possibility of ordering volitional intensity according to the more and the less, is implicit even in purely spiritual experience. But we need not go so far in arguing for the power and scope of Descartes' method of figuration. The evidence of the intention of the *Regulae* to systematise our ability to configure and solve problems of mathematics and the sciences, when added to Descartes' historical influence, is evidence enough.

Conclusion

Elsewhere I have argued that imagination is key to understanding Descartes' thought, especially before 1630.[28] The present essay represents a deepening of that argument. But in conclusion I wish not to turn to the more general issue of imagination, but to make some suggestions about where the question of figuration leads us.

One issue is how Descartes used figures after he abandoned the *Regulae*, that is, around 1630 and thereafter. Readers of the *Dioptrique* and the *Météores*, both attached to the *Discours*, know that Descartes was fond of using not just geometrical diagrams but also illustrations suggestive of analogies.[29] This indicates a continuing confidence that relationships and proportions exhibited in one situation or figure can represent similar situations, or even a general phenomenon. However, he also lost confidence in the ability of the physics of the world and the physiology of our bodies to convey the impressions of the world to our brains in exact form. As the power of God to create the world in different ways came to play a more explicitly central role in his thought, his trust in our ability to know with certainty all the contingent circumstances of experience declined. Nevertheless, his increasing emphasis on the identity of geometrical space with matter, an identity resting on the eternal truths created by God and on the guarantee that God does not deceive us, provided a foundation for the scientific certainty and relevance of geometry correlated with algebra, of figuration correlated with calculation.

The very particles of the infinitely divisible continuum of geometrical space, while they tend to move in straight lines, are constantly subjected to the forces of collisions with countless other particles. Each collision produces an impulse on the particle that can be represented by a straight line; the motion of that particle is itself a result of all these impulses; and the motions of all particles, that is, all the motions in the universe, are the result of the grand, dynamic geometry of the cosmos-machine. The universe might be conceived as the proportional compass of all proportional compasses: one that constantly calculates – that is, undergoes – all its results. Perhaps only God could track this complexity, but its fundamental principles are intelligible to human beings because it is based on geometry and the analogy to simpler machines. The *Géométrie* and *Le Monde*, two post-1630 works, provide the intellectual underpinnings for this conception.

What, finally, is the role of algebra in Descartes' post-1630 mathematics and science? Just as in the *Regulae*, the symbolism of algebra is a way to keep track of geometrical and physical situations conceived in geometrical fashion. Every manipulation that a symbolic formula/equation can be subjected to has its analogue in the geometrical and physical realms. But this perhaps is the key to understanding why algebra always remained an ancilla in Descartes' science and mathematics. To put things simply: algebra is not about anything at all if it is not correlated with what it refers to or names. If a and b do not stand for anything, then neither does $a + b$, much less any more complex formula into which it might be incorporated. Algebra per se symbolizes relations, but the symbolisation has no significance unless it formulates a real problem. To put it in a formula: algebra does not signify anything apart from use, and it does not mean anything except insofar as it implicitly embodies a theory of proportional relationships that can exist in concrete cases. Algebra as a science is therefore potential knowledge only; geometry on the other hand is real knowledge, because its figures are not mere signs or memory marks, but rather determinate figures implicitly proportionalised to all other figures in all measurable spaces. They do not merely represent relationships, they also embody them.

This is an attitude quite foreign to the average contemporary student of algebra and calculus, although the point that seems to count for Descartes is not unknown to theorists of language and philosophers of the foundations of mathematics. Our instinct is to think that the truer, or at least the more powerful, sciences are the more abstract; thus algebra is more powerful than geometry, and geometry is more clearly a science the more it is formulated in abstract axioms and undefined terms. Descartes is ordinarily thought to be an ally in this progress towards a highly rationalised abstract truth; but, at least in his understanding of figuration and its importance, he seems to be closer to an older way of thinking about figures and their reality that to us appears largely superseded. Whether it has actually been superseded is another question entirely; nevertheless, the case of Descartes' method of figuration brings us to that question's heart.[30]

Notes

1 For example, see John A. Schuster, 'Descartes and the Scientific Revolution, 1618–1634: An Interpretation' (PhD diss., Princeton University, 1977), and Chikara Sasaki, 'Descartes's Mathematical Thought' (Ph.D. diss., Princeton University, 1989).

2 From AT x. 102.

3 This process, generalised to the case of the equation $ax^2 + bx + c = 0$, leads directly to the quadratic formula.

4 See, for example, Edna E. Kramer, *The Nature and Growth of Modern Mathematics*, 2 vols. (Greenwich, Conn., 1970), i. 137–8. Cossic algebra was named from the Italian word *cosa*, 'thing'. In cossic notation, the unknown in a problem was represented not by the letter *x* but by a stylized symbol, and higher powers of that unknown were represented by quite different symbols. Thus the relationships between powers were not as perspicuous, and problems not as easily solved, as with the modern notation that Descartes eventually developed. For an example from the cossic tradition, see the higher-order problem from Christopher Clavius' *Algebra* as presented in Sasaki, 'Descartes' Mathematical Thought,' 94–6.

5 AT x. 334–5.

6 Beeckman and Descartes already knew the answer to the question, that the value of *x* was 7, so that Figure 10.2 was drawn accordingly, that is, with the side of the large square *aebc* 7 units long. But we would not in general start out with the answer already in mind, so our initial representations would be 'sloppy' and approximate and could not be corrected until an advanced stage of working out the problem. In fact this is a standard technique of mathematical method: the stage of analyzing the problem would be followed by a synthesis, that is, we would work backwards from the solution we had come upon and reconstruct all the previous stages of the problem accordingly, but now in an exact and correct way. The ancient Greek geometers had already recognized this, since their aim was to show how, from an initial figure and a set of givens, one could construct a solution step-by-step using a straightedge and a two-legged compass. The crucial step in solving the present problem is determin-

ing, by halving 6 to get 3, that we need to mark off exactly three units of length from the vertex *c* along both sides of the square. In the phase of initial problem analysis we can arbitrarily choose the unit length at our convenience, provided it makes sense in proportion to the figure we have drawn. Thus it would not make sense to let that unit be larger than the side of the large square *x*, or even so long that three of those units would be longer than *x*.

7 On the nature and use of these compasses, see the examples given later in this section.

8 See William R. Shea, *The Magic of Numbers and Motion* (Canton, Mass., 1991), 51–7.

9 The relevant *Cogitationes privatae* note is at AT x. 219. Beeckman recorded a fuller discussion (and emendation) of Descartes' argument in his *Journal*; it, and Figure 10.4, are found at AT x. 58–61. For an analysis of the deficiencies of Descartes' approach and Beeckman's improved (and correct) understanding, see Shea, *The Magic of Numbers and Motion*, 15–22.

10 Galileo had given a new impetus to the search for such devices a decade earlier.

11 See AT x. 232–3.

12 If one given line measures two units long, and the second measures eight, a single mean proportional between the two will measure four, since the mean proportional between any two numbers or lengths a and b is the number x such that $a/x = x/b$ (thus $x^2 = ab$, so $x = \sqrt{ab}$, a simple example of how proportion problems give rise to algebraic equations). Two mean proportionals between a and b are the numbers x and y such that $a/x = x/y = y/b$ (which leads to the equation $x^3 = a^2b$); three mean proportionals are the numbers x, y, and z such that $a/x = x/y = y/z = z/b$ (which leads to the equation $x^4 = a^3b$). In Figure 10.6, if YB and YD are the given lines, YC is the mean proportional; between YB and YE the two mean proportionals are YC and YD; between YB and YF the three mean proportionals are YC and YD and YE; and so on.

13 For a brief explanation of these and other devices, see Shea, *The Magic of Numbers and Motion*, 35–48.

14 For example, in the 1628 conversations with Beeckman he pointed out that quadratic equations could be represented by both line lengths and plane areas, and in one of his explanations he pointed out that cubic equations could be represented by cubes, and equations of order four and higher by cubes of varying physical properties like colour, density, and material. For a discussion in the context of the art of mnemonics, see Dennis L. Sepper, *Descartes' Imagination: Proportion, Images, and the Activity of Thinking* (Berkeley, 1996), 105–8.

15 To be found in Aristotle, *De anima*, bk. 2, ch. 12, 424a18–22.

16 AT x. 412.

17 AT x. 415.

18 AT x. 91–2. See Sepper, *Descartes' Imagination*, 37–46, for a discussion.

19 AT x. 413.

20 *Dioptrique*, AT vi. 137–8.

21 AT x. 438.

22 Thus he may well have believed that there was a kind of figurate calculation that allows us to mentally produce real composite colours out of elementary ones.

23 AT x. 439.

24 AT x. 381.

25 AT x. 452.

26 This term is explained in Sepper, *Descartes' Imagination*, 150–1 and 159–62. It is derived from the Greek term *mathesis*, which Descartes understood as meaning 'discipline' and that assures the character of knowability to everything that is

an object of science. Mathematics participates in the mathetical in a preeminent fashion, but the principles of knowability are wider in extension than mathematics.

27 AT x. 381.

28 In Sepper, *Descartes's Imagination*, passim. A small but key fragment of evidence is the 'two-imaginations note' from the *Cogitationes privatae*, which begins: 'As imagination uses figures to conceive bodies, so intellect uses certain sensible bodies to figure spiritual things' (AT x. 217).

29 For example, a vat of grapes in their juice is used to suggest how (assuming light to be a kind of pressure) the pressure exerted by light might move around opaque microscopic obstacles while continuing to proceed away from its source in a more or less straight-line path (in *Dioptrique*, AT vi. 86), and a blind man is presented using two sticks to triangulate the position of an object as an analogy for how our eyes might determine distances (in *Dioptrique*, AT vi. 135).

30 Here I will only mention that the later Wittgenstein and also intuitionist/constructionist theories of mathematics share at least some of Descartes' concerns. For a careful account of the epistemological and metaphysical presuppositions of the ancients' understanding of geometry and number, see Jacob Klein, *Greek Mathematical Thought and the Origin of Algebra*, trans. Eva Brann (Cambridge, 1968).

11 The rainbow

A privileged epistemological model

Jean-Robert Armogathe

Of all physical phenomena, the rainbow is that which has excited the greatest imagination and surprise. It is not by chance that the Ancients took it for the mother of *thauma*, admiration. It is an astonishing and wonderful phenomenon. The scientific imagination and the desire to explain have, nevertheless, succeeded over the centuries in separating out three questions: the shape of the rainbow, the conditions under which it is visible, and its colouring.

The shape of the rainbow gives rise to the first surprise: it is in fact a perfectly geometrical figure, a circle, or rather an arc of a circle. Before crystals were studied, the domain of nature and that of geometry appeared distinct, even contradictory. And the rainbow appeared as a strange geometrical figure in the field of natural phenomena. In the *Meteorology*, Aristotle – followed by many others after him – assigned to the point of 'reflection' on the cloud opposite the sun a geometrical locus, the base of a cone, which is, a century before Apollonius, the Apollonian circle. Aristotle's very precise geometrical demonstration accounts for the shape (an arc rather than a complete circle) and its disappearance when the sun is at its zenith. Nevertheless, while giving a geometrical formulation, Aristotle is not able to provide an satisfactory physical explanation. We must wait several centuries for the Oxford Franciscan physical theorists for that to be achieved. In his *De Iride*, Robert Grosseteste separated out three subordinate sciences of *perspectiva*: as well as vision and catoptrics (which deals with reflection), there is dioptrics, which is the science of refraction:

> The ray passes through many (thousands of) diaphanes of different kinds: and in the passage from one to the other the ray is refracted at an angle. What we see is not the result of a direct path; it comes about rather through a succession of several rectilinear segments formed through these angles.[1]

Grosseteste states that this science has remained completely ignored in the West until his own time. He tries desperately to provide a law of refraction ('what the angle of the ray is'), but the absence of mathematical tools only allows him to think of it by extrapolating from reflection ('let us imagine'). There were two contemporary scientists, the Persian Kalam al-Din al-Farisi (died c. 1320) and the German Dominican Theodoric of Freiberg (died c. 1311), who succeeded in explaining, in an experimental way and quite independently of one another, the formation of the primary bow and the secondary bow, the first by means of two refractions and one reflection, the second by means of two refractions and two reflections.

The visual perception of the colours of the rainbow is also a peculiar phenomenon: the 'object' is one which disappears when one approaches it, and which seems to have no other consistency than a strange play of light. Finally, the colouring seems inexplicable, and the richness of its colours make the rainbow a phenomenon unique in a world dominated by subdued colours and black and white.

All the 'meteorological' manuals of the sixteenth and seventeenth centuries – that is, the commentaries on the Aristotelian *Meteorology* – repeat the traditional explanations with some new personal additions, often starting from observations or experiments. In this respect, the *De Iride* of Mersenne, which appears in the unedited continuation of his *Quaestiones in Genesim*,[2] gives us an idea of the state of the question around 1620 (even though it does not mention the important study of Marc-Antoine de Dominis[3]).

It is hard to understand the exemplary importance of this question today, and yet it is under pressure from his correspondents that Descartes, in 1629, was forced to abandon working on his *Meditationes* in order to 'examine systematically the whole of meteorology'. It is not a question of a selection, but one of an exhaustive inventory ('systematically'):

> By I now think I can give some explanation of it, and I have resolved to write a short treatise on the topic which will contain an account of the colours of the rainbow, something which has given me more trouble than all the rest.'[4]

He complains that the mild winter in Holland in 1629–30 has not allowed him to 'make any observations concerning meteorology'.[5] In 1636 the Treatise is ready, and Descartes decides to join it with the *Dioptrique* as a 'sample' of his method.[6] He is sufficiently satisfied with the results to write to a Jesuit, Father Fournet:

> It seems to me that there is no-one who has a greater interest in examining this book than the members of your Society, for I can already see that what it contains (especially as far as meteorology is concerned) will be accepted by so many people that I just do not know how they will be able to teach these subjects without either refuting or accepting what I have written.[7]

From 1625 onwards, Mersenne had been concerned with the rainbow and the origin of its colours.[8] The Louvain theologian and scientist Libert Froidmont published his *Meteorologica* in 1627,[9] and in 1630 Gassendi published his response to the problem based on the observations made at Rome by the Jesuit Christopher Scheiner.[10]

All these treatises, that of Descartes included, began with the same claim, one which goes back to the Bible, that the rainbow is 'a singular work' (Froidmont), that its beauty outshines everything else (Coimbra commentators), and Maurolico tells us that while many have written about the rainbow, no one has explained it satisfactorily.[11] Descartes puts these things concisely:

> The rainbow is a wonder of nature so remarkable, and its cause has been so ardently sought for so long by so many good minds, and so little known, that I could choose nothing more appropriate to show how, with the method we are using, we can arrive at knowledge not possessed by any of those whose writings are available to us.[12]

A common bond, difficult and marvellous, ties light and geometrical treatment, and this is enough to interest Descartes and stimulate reflection.

The phrase 'those whose writings are available to us' is very useful: it allows one simultaneously to distance oneself and to mention, without having to cite any names. The Latin translator who edited the *Specimina philosophiae*, Coucelles, was well aware of the difficulty. He employed a maladroit Gallic figure, '*ii quorum scripta ad nos peruenere*',[13] instead of the Latin expression '*scriptores prisci*' or '*priores*', which one would expect. Who are these predecessors, mentioned anonymously so that we might be all the more convinced of their incompetence? One might first think, as Leibniz and Newton will do, of Marc-Antoine de Dominis. But Dominis' work was rare (N.J. Poisson was unable to find a copy of it) and it is not absolutely certain that Descartes knew it: remember that Mersenne, well informed as he was, did not cite it. He had probably read the Coimbra commentators at La Flèche, and he had read Maurolico, whom he cites. Finally, he had certainly read Froidmont: he also knew his *Labyrinthus de compositione continui* of 1631.

Plempius had informed Descartes about the *Meteorologica* of 1627 (published in Amsterdam around 1630). The commentary on the writings of Seneca (3rd. edn., 1632) is also very instructive, above all on the *Quaestiones naturales.* It is Froidmont who provides him with the essentials of his documentation: a general exposition of 'all those whose writings are available to us', containing many different observations and above all lively criticisms of all earlier attempts at explanation of the phenomenon. A single glance at the list of contents in Froidmont shows us this. Froidmont will, through the intermediary of Plempius, be one of the recipients of three copies of the *Discours* and the *Essais* which Descartes will send to

Louvain. Froidmont will quickly send his objections, which bear above all on the *Météors* (nine objections, compared with three alone for the *Discours* and six for the *Dioptrique*). These objections will be sent so quickly that Descartes will express surprise at receiving them by September 1637. Copies of this debate circulated in Holland, and Pollot was able to purchase one before the end of 1637. He will send the dossier to Huygens, who will immediately re-copy it. Rivet will be equally familiar with it, and a little later, in Groningen, Schoockius will cite this exchange of correspondence in the course of academic proceedings.[14]

Descartes' reading of Froidmont is easy to identify: we find in him the reference literally reproduced in the text that Descartes cites in a long letter to Mersenne of 18 December 1629, in which he asks: 'Please tell me who the author is who relates that "Dutch sailors saw three suns separated from each other by a pattern of six rainbows" '.[15] Froidmont had also provided other 'observations' related by Descartes, as we shall see below.

Descartes proceeds by trying to lead the meteorological phenomenon to the theory of vision, then to an experiment with a large droplet (a spherical vessel full of water (Figure 11.1)), then to an experiment with a prism. Doubtless he was able to admire the fountains of the Italian villas – 'thus the experience demonstrated in several fountains' – where Montaigne had already admired the formation of coloured bows:

> The sun falling above it gives rise, both at the bottom of this pool and in the air, and all around this place, to a rainbow so natural and so conspicuous that it is indistinguishable from those we see in the sky. I had never seen this elsewhere.[16]

This observation is, moreover, also related by Mersenne.[17] It is a commonplace in all of Descartes' predecessors, and Froidmont even specifies that he has used a urinal ('*aut uitrum etiam uulgare uinarium*'[18]), that is, 'the large glass flask, wholly round and completely transparent' of which Descartes speaks.

This instrument allows him to achieve his first result: the ray is always in the region of 42° for the primary bow, and 52° for the secondary bow. The first figure had been given very frequently, whatever Descartes might say, in a dozen or so manuscripts and printed books between 1269 and 1611; the second is more accurate than Maurolico's figure of $56\frac{1}{4}$°. Maurolico, who, for theoretical reasons, gives 45° for the primary bow, is surprised at the discrepancy with observation (which Descartes forgets to mention when he criticises him), and tries to explain this discrepancy by the shape of the vessels, as Froidmont also relates.[19]

But it is here that Descartes introduces his novel contribution to treatises on the rainbow: the idea that it is not enough to explain where the rays originate. To give a comprehensive explanation, we need to provide

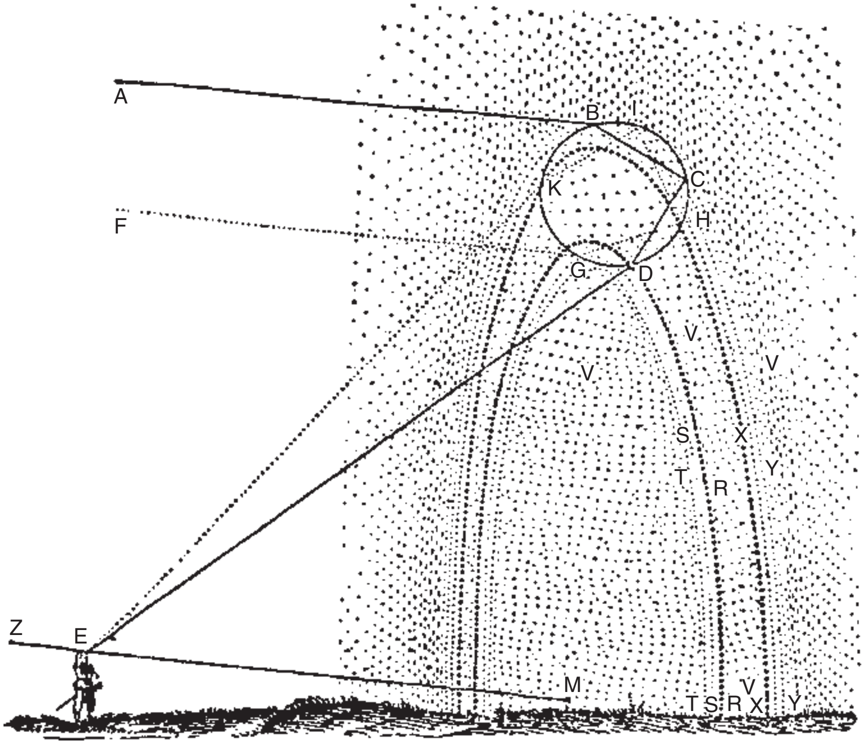


Figure 11.1

an account of these rays: why is it that only those rays which strike the eye at the angles of 42° or 52° are efficacious?

> To resolve this difficulty, I looked to see if there was something else in which they appeared in the same way, so that by comparing these with each other I would be in a better position to gauge their cause.[20]

What we have here, at one and the same time, is both a point of method – dividing the problem up into as many difficulties as need to be resolved – and a transition from the experimental tradition to mathematical reasoning ('by comparing these with each other'). The instrumentation Descartes deploys remains rudimentary: the prism rests on a plank in which a hole is pierced, and the refracted beam is received on a perpendicular screen (Figure 11.2). Descartes seems to cling to the tradition that would have the spectrum produced by light and shade, and he emphasises the need for shade 'at the extremity of the light.' This classical view[21] had been combated by Wendelin ('*colores scilicet Iridis esse tales in ipso Sole*'), which Froidmont cites and contradicts.[22] But Descartes is not hindered by

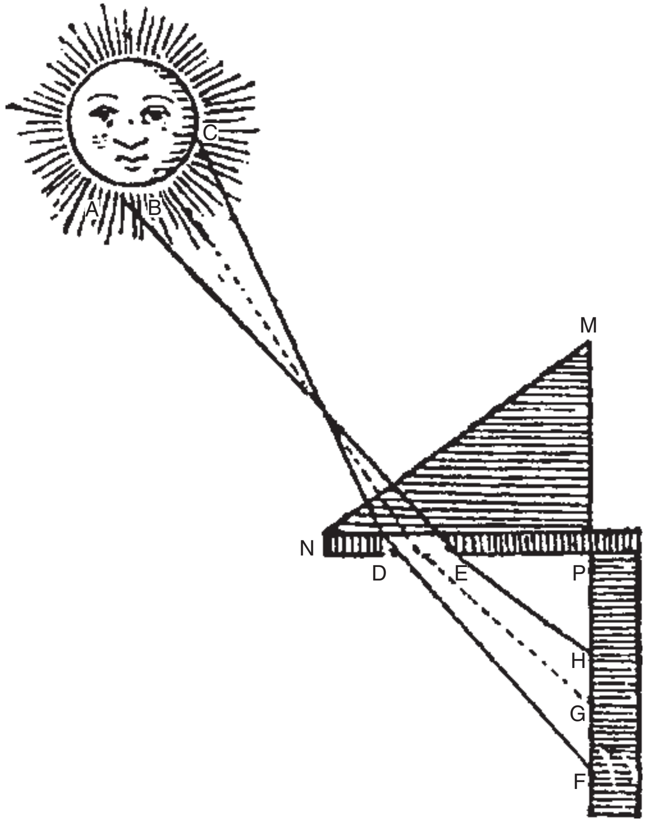


Figure 11.2

these difficulties, because he pursues a precise goal: to give an account of colours in terms of the conception of light set out in the *Dioptrique*.

We will not set out the Cartesian theory in detail here. It is enough to recall that light is the motion of a very subtle matter when very small corpuscles roll in the pores of terrestrial bodies. White light is produced when the rotations of the corpuscles are equal to their displacement in a straight line. Colours are produced by modifications brought about at the peripheries where the media meet:

> And it seems to me that it is very evident from all of this that the nature of colours appearing [at this point] consists just in the parts of the subtle matter which transmit the action of light having a much greater tendency to rotate than to travel in a straight line. As a consequence, those that have a much stronger tendency to rotate cause the colour red, and those which have only a slightly stronger tendency cause yellow.[23]

And at the other extreme of the band, green appears where the corpuscles turn slightly less rapidly, and blue where they turn even less rapidly. The violet band at the extremity is explained by the presence of pink, 'the cause of which is without doubt the same as that which usually slows down the rotation of the parts of the subtle matter when it has enough strength to change the position of some of them and increase their rotation, while slowing that of others'.

Having arrived at his explanation, Descartes points to the need to reaffirm that in all this 'reason accords perfectly with experience', which allows him to reject the distinction between apparent colours and real colours.[24] From the unity of colours, those of the rainbow as much as those of coloured bodies, Descartes suddenly brings into view a radical shift in his reasoning: it is the only positive occurrence of the verb 'to doubt' in the *Essais* of 1637 (although the expression 'without doubt' is used very frequently): 'At first I doubted whether colours were produced (in the rainbow) in exactly the same way as in glass.'

The detour via calculation becomes necessary here: it is indeed here, and not in the preceding experiments, that the originality of Descartes and his method will be manifested. He is in fact not the first to have made these observations, and the experimental results are scarcely better than those of his predecessors. His explanation of colours, which the Jesuit Grimaldi recognised as insufficient in his *De lumine et coloribus*,[25] will be definitively superseded by that of Newton. But it is in his calculations that the superiority of Descartes' treatise over numerous other treatises of the time is clearly shown. It is here we find the man who calculated, and who calculated laboriously: 'having taken my pen and calculated in detail all the rays that fall on the various points on a drop of water'. For his detailed calculations, Descartes had recourse to a refractive index of water 'a little greater than 3 to 4,' or, more precisely, he tells us, of 187 to 250, which corresponds well with the refractive index accepted today for his ray D at 20° C: 1, 333. He takes it from Witelo's tables, although he does not trust these completely.

Having explained why the colour arrangement of the exterior bow is the inverse of that of the primary bow, he concludes: 'I believe that there remains no difficulty in this matter, unless it perhaps concerns the irregularities which one encounters here.' He then sets about replying to the problems raised by Froidmont, presenting them as observations which have been related to him, telling us that 'I have been told that there has sometimes also been observed . . .'. In fact, as Ettore Lojacono has established, it is Reiner Gemma who noted an unusual upturned rainbow on 20 September 1560, and Froidmont reports this. Moreover, Descartes writes that he has also been told about 'a third bow above the two usual ones'. It is also in Froidmont (writing against Aristotle), following Vicomercati, that we find the story of three bows: Snell speaks of six bows being witnessed, Witelo speaks of four being seen at Padua, while the Coimbran commentators speak of three. In addition, the episode of the King of

Poland having seen three suns at the same time in 1525[26] derives from Vicomercati and Gemma, and is repeated in Froidmont.[27]

Descartes refuses to allow a third bow and tries to explain away the mention of it in terms of an error of observation, which makes it reminiscent of 'an invention which makes it appear that there are signs in the sky', referred to in the table of contents as 'signs in the sky which resemble wonders'. What is at issue here is an ancient project of marvels, and Descartes' first notebooks – the *Thaumantia Regis*[28] – carry the traces of it. In one way, the mathematization of the 'wonder' of the rainbow brings it to an end, by evoking other 'wonders' of human origin, the fruits of scientific knowledge. The refusal to marvel, the concern with scientific explanation, is prolonged in a new marvelling whose provinces are known, and which reproduces by art what nature proposes. Scientific knowledge takes the place of admiration, and it procures the same objects.

We can now understand better why Descartes was able to propose 'a brief sample' of his method 'in my account of the rainbow'.[29] He explains in general terms something which cannot be shown any other way in the three essays, namely the use of his method, 'because it prescribes an order for seeking things which is very different from that which (he believed) should be used for exposition'. Setting out his results in the *Essais*, he believed that he was able to explain them. Explanation is a key word in Cartesian epistemology: confining ourselves to the Latin text of the *Specimina* (the Latin translation of the *Discours*, *Météors* and the *Dioptrique*), there are forty-seven occurrences of *explicare* (often in the context of first-person statements) and nine of *explicatio*, making this semantic cluster the most striking in the lexicon of the text.[30]

'I have, however, given a brief sample of it in my account of the rainbow': Descartes' description of the rainbow reveals the 'order of seeking things' as much as that of 'explaining them'. We have seen that he found in his predecessors, in Froidmont in particular, all the elements of his research. If the epistemological example does not lend itself so much to innovation as far as results are concerned, it is the road (the 'method') reserved for discovery that Descartes has been able to describe. In this sense, it is not so much the rainbow as this that is the model of the scientific step that Descartes takes beyond the commonplaces of meteorology of his time.[31]

Notes

1 *Die philosophischen Werke des Robert Grosseteste*, ed. Ludwig Bauer (Münster, 1912), 73.
2 BNF, ms. lat. 17262, pp. 123–32, in *Correspondance du P. Marin Mersenne* (Paris, 1936), ii. 649–66.
3 *De radiis uisu et lucis in uitris perspectiuis et Iride tractatus* (Venice, 1611).
4 To Mersenne, 8 October 1629; AT i. 23.
5 AT i. 127.
6 AT i. 559.

7 AT i. 455.
8 *Correspondance du P. Marin Mersenne* i. 237 and 242.
9 *Meteorologicorum Libri V* (Anvers, 1627).
10 *Parhelia, seu Soles IV spurii qui circa uerum apparuerunt Romae die 2à martii 1629 et de eisdem Epistola ad henricum Renerium* (Paris, 1630).
11 *Theoremata* (Lyons, 1613), 57–74.
12 AT vi. 325.
13 AT vi. 700.
14 On this, see AT xii. 241.
15 AT i. 84.
16 *Journal de voyage de Michel de Montaigne* (Paris, 1992), 129 (Villa d'Este).
17 *Correspondance* ii, 649.
18 Froidmont, op. cit. 358.
19 Ibid., 365.
20 AT vi. 329.
21 Vitellion, *Perspectiva* (Nurenberg, 1535) fol. 288r; Telesio, *De Colorum generatione* (Naples, 1570).
22 *Meteorologica* (Anvers, 1627), 372.
23 AT vi. 333.
24 This is the distinction made by the Coimbra commentators, 'duo genera colorum', between temporal colours and true or permanent colours: *In III libros de Anima* (Cologne, 1600), ii. 7, quaest II and III, pp. 221–2.
25 Francesco Maria Grimaldi, *Physico-mathesis de lumine et coloribus* (Bologne, 1665).
26 Not 1625, as it says in the printed edition of 1637 reproduced in AT.
27 Froidmont, op. cit., 410.
28 *Cogitationes privatae* AT x. 215–6; Letter of Sept. 1629 to *** (AT i. 21); *Recherche de la vérité* (AT x. 504). On the experiment carried out in Paris (around 1625–6) with Villebressieu, see P. Borel, *Vita Renati Cartesii Compendium* (Paris, 1656), 10.
29 Letter to [Vatier], Feb. 1638, AT i. 559.
30 For ch. 8 of the *Meteora*, there are five occurrences on six pages of text in AT.
31 Translated by Stephen Gaukroger.

12 Descartes *opticien*

The construction of the law of refraction and the manufacture of its physical rationales, 1618–29

John A. Schuster[1]

Introduction

In his *Dioptrique* of 1637 Descartes raised numerous difficulties and puzzles. For example, he deduced the laws of reflection and refraction from a model: the motion of some very curious tennis balls. Descartes' contemporaries tended not to see any cogency in this model, nor did they grasp the theory of dynamics upon which it is based.[2] Later, questions were raised about how Descartes had obtained the law, if not through his dubious deduction. Had Descartes plagiarised it from Willebrord Snel? If not, where had it come from?[3]

This chapter cuts a path of reconstruction through these controversies. First it is shown that the tennis ball model for reflection and refraction links quite coherently to Descartes' impulse theory of light *through* his dynamics of micro-corpuscles. That dynamics was mooted in his earliest natural-philosophical speculations, and first worked out in some detail for *Le Monde* between 1629 and 1633. Nevertheless, the tennis ball model and its dynamic basis posed a number of problems, seen by Descartes and his critics. The strengths *and* the weaknesses of the model will provide clues and tools for the main theme of the paper, a reconstruction of how the law of refraction was discovered. Given that reconstruction, we shall finally be able to explore some of the complicated relations between Descartes' geometrical optics and his attempts at mechanistic explanation in the 1620s.

Cartesian dynamics in *Le Monde*

This section examines the earliest articulated version of Descartes' dynamics, as offered in *Le Monde*. This will set the stage for our analysis of the tennis ball proofs in the *Dioptrique*. These will be fully explicated and consistently reduced to Descartes' actual mechanical theory of light by means of an understanding of this dynamics.

Descartes' dynamics of micro-particles had nothing to do with the mathematical treatment of velocities, accelerations, masses and forces. Rather it was concerned with accounting for the motion, collision and tendency to motion of corpuscles. Descartes held that bodies in motion, or even merely tending to motion, can be characterised from moment to moment by the possession of two sorts of dynamic quantity. First, there is the absolute quantity of the 'force of motion'; second, there are the directional modes of that quantity of force – the directional components along which the force or parts of the force act. These directional modes of the quantity of force of motion Descartes termed actions, tendencies, or, most often, determinations.[4] Whilst the rudiments of this dynamics of instantaneously exerted forces and determinations dates back to Descartes' earliest work, it was first articulated in *Le Monde*.[5]

Descartes explains natural change mainly by instantaneously occurring corpuscular collisions. At the moment of a corpuscular impact, the God of the Cartesians instantaneously adjusts the quantities of force of motion and the determinations that will characterise the corpuscles concerned in the instant after the impact. God does this by following certain laws and rules of impact he has framed and 'ordinarily' follows. He, God that is, considers the force and determination relations of the two bodies just prior to impact, and upon impact he instantaneously rearranges those forces and determinations in accordance with the rules he has laid down. The laws and rules of impact are Divinely ordained prescriptions, stating what God will do about redistributing the dynamic quantities, given the conditions of the impact. Consider Descartes' first 'rule of nature' in *Le Monde*, which reads as follows:

> Each part of matter always continues to exist in the same state as long as other bodies do not constrain it to change that state. If it has a certain size, it will never become smaller, unless other bodies divide it, if a body has stopped in a given place, it will never leave that place unless others force it out; and if it has once commenced to move, it will continue along with the same force, until other bodies stop or retard it.[6]

We may take this to assert the conservation of the motion (or rest) of a body in the absence of external constraints. Closer inspection reveals a telling point. Descartes slips into speaking of the 'force of motion'. This is the quantity which is conserved. This is the force of motion we have been talking about. Descartes uses the term in relation to his voluntarist understanding of ontology: God must continually support (or re-create) bodies and their attributes from moment to moment. This implies that in the final analysis a body in phenomenal translation, in motion, is really being re-created or continually supported at successive spatial points during successive temporal instants. In addition, and this is the key point, in each of those instants of re-creation, it is characterised by the Divine injection of a certain quantity of 'force of motion'. We should view the instantaneously conserved 'force of motion' as a kind of quantity of efficacy (the phenomenal mirror of the instantaneously injected Divine action).

The third law of motion in *Le Monde* specifies the direction in which the Divinely conserved *quantity* of force of motion is to act.[7] The force of motion is directed along the tangent to the path of motion at the point under consideration. We have to be careful here. The third law does *not* say that merely a direction is conserved. Rather, it asserts that a quantity of force of motion is annexed to a privileged direction. That is, the law specifies a *directional quantity of force of motion*. It says that in the absence of external constraint, this directional quantity of force of motion would be conserved by God from instant to instant. This directional quantity of force of motion is, of course, that '*determination*' discussed above.[8] Let us call the directional quantity of force of motion directed along the tangent to the path of motion at a given instant the *principal determination of a moving body*; following Descartes one can decompose that directional quantity into components, also called determinations. In any given case, mechanical conditions and the spatial relations of bodies dictate which components of the principal determination come into play. We are going to see that in the demonstrations of the optical laws, the reflecting or refracting surfaces effectively dictate which components of the principal determination of a moving tennis ball come into play in the collision. The only other thing we have to remember is that determination, like force of motion, is a dynamic property predicated of moving bodies (or of bodies tending to motion), from instant to instant. Just as force of motion is injected by God from instant to instant, so is determination, which, according to the third law, is only the directional magnitude of that force and the components into which it may be resolved. As God maintains or alters from moment to moment the absolute quantity of force of motion, so he also maintains or alters instantaneously the directional manifestations of that force – what Descartes calls the determinations.

Let us consider Descartes' chief example of the use of these concepts (see Figure 12.1). Consider a stone rotated in a sling. Descartes analyses the dynamic condition of the stone at the precise instant that it passes point A. By the first and third laws of motion, the force of the motion of the stone is directed along the tangent, that is, along AG. If the stone were released and no other hindrances affected its trajectory, it would move along ACG at a uniform speed reflective of the conservation of its quantity of force of motion.[9] However, the sling constrains the privileged, principal determination of the stone and deflects its motion along the circle AF. Descartes considers that the principal determination along AC can be divided into two components: one is a 'circular' determination along ABF; the other a centrifugal determination along AE. For present purposes, let us ignore the curious circular tendency. To discuss it would lead us further than we need to go into Descartes' manner of treating circular motion.[10] What Descartes is trying to do is decompose the principal determination into two components: one along AE completely opposed and hindered by the sling – so no actual centrifugal translation can occur –

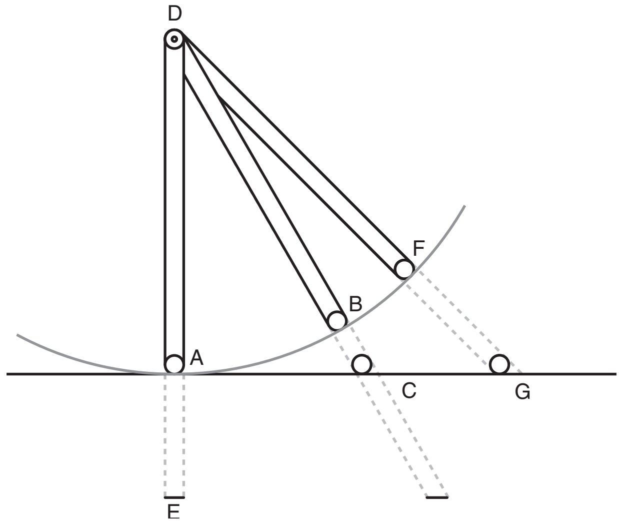


Figure 12.1

only a tendency to centrifugal motion; the other along the circle, which is as he says, 'that part of the tendency along AC which the sling does not hinder'.[11] Hence it manifests itself as actual translation. The choice of components of determination is dictated by the particular configuration of mechanical constraints on the system.

Leaving aside Descartes' theory of elements and his cosmology, his *basic* theory of light is that light is a tendency to motion, an impulse, propagated instantaneously through continuous optical media. So, light is or has a determination – a directional quantity of force of motion. Note that light, as a tendency to motion, can have a greater or lesser quantity of force – we can have weak light impulses or strong ones – but the speed of propagation in any case is instantaneous. This distinction between the force of light and its instantaneous speed of propagation is about to become very important, having been neglected for three and a half centuries.

Making sense of the proofs of the laws of reflection and refraction in the *Dioptrique*

We may now turn to the laws of reflection and refraction as they are demonstrated using the tennis ball model in the *Dioptrique* of 1637. First let us look at the case of reflection (see Figure 12.2). Descartes takes a tennis ball struck by a racket along AB towards surface CBE. We neglect the weight of the tennis ball, its volume, as well as air resistance.[12] The reflecting surface is considered to be perfectly flat and perfectly hard: upon impact it does not absorb any of the force of motion of the ball. The

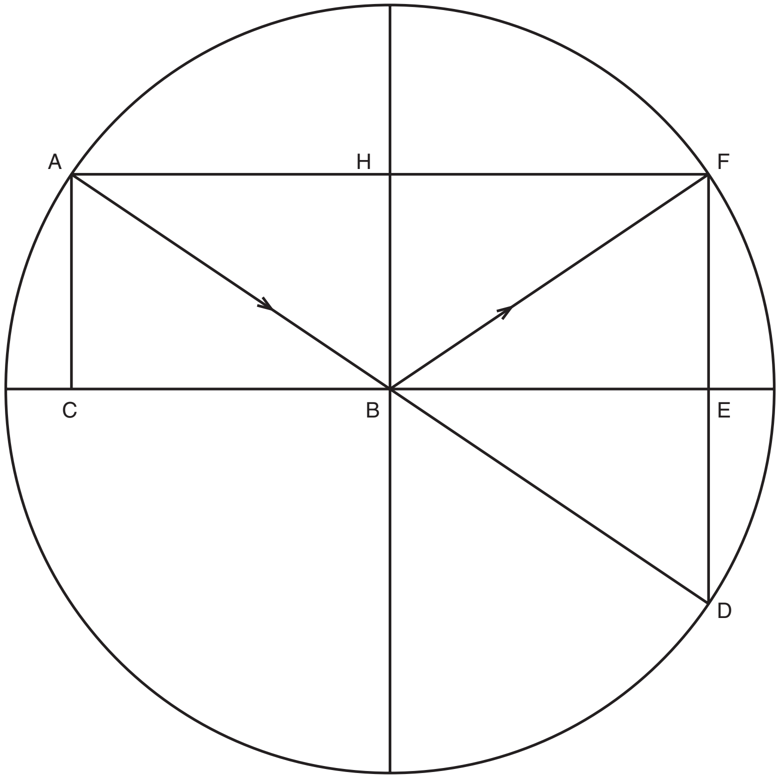


Figure 12.2

tennis ball is now virtually a mathematical point in motion; it bears a certain quantity of force of motion, divisible into directional components, or determinations.[13] The demonstration of the law of reflection is carried out as a geometrical locus problem. Descartes places two conditions upon the dynamical characterisation of the ball. First, the total quantity of its force of motion is conserved before and after impact – no force can be lost to the surface. Second, the component of the force of motion parallel to the surface is unaffected by the impact. Descartes expresses these conditions geometrically, and uses them to determine the quantity and direction of the force of motion of the ball after impact with the surface.[14]

For the first condition, the conservation of the quantity of force of motion, we draw a circle of radius AB about B. Assume that prior to impact the ball took time *t* to travel along AB. Having lost no force of motion to the surface, the ball will, in an equal time *t* after impact, be located somewhere on the circle. The second condition is that the parallel determination, the component of force of motion along the surface, is unaffected by the collision. In time *t* before impact, while the ball traversed AB, Descartes says that the parallel determination 'caused' the ball to traverse the horizontal distance between AC and HB. In an equal period of time *t* after impact, the unchanged parallel determination will 'cause' the ball to move an equal distance towards the right.[15] We represent this by drawing FED so that the distance between FED and HB equals that between HB and AC. At time *t* after impact the tennis ball must lie somewhere on this line FED *and* it must also lie on the circle; that is, it must be at F or D. The surface is impenetrable, so at time *t* after impact the ball must be at F. Geometrical considerations immediately show that the angle of incidence is equal to the angle of reflection.[16] This proof never takes into consideration the behaviour of the component of force of motion perpendicular to the surface, the normal determination, as we shall term it.[17]

I now propose to do something Descartes refused to do in the *Dioptrique*, even though it is perfectly feasible and follows easily in his overall natural-philosophical perspective. I shall translate the tennis ball proof into the terms of Descartes' theory of light, using his dynamics. This is not difficult to do, because the tennis ball has already been stripped of all properties except location, force of motion and its determinations. It is already virtually a mechanical impulse, and that is all a ray of light is in Descartes' theory. *So we can assert the same things about the tennis ball at the instant of impact as we would assert about a ray of light at the instant it meets a perfectly hard reflecting surface.*[18] Consider in Figure 12.2 a light ray, AB, a line of tendency to motion, or determination, impacting the surface CBE at B. The surface is perfectly hard, therefore the magnitude or intensity of the impulse is conserved. The parallel component of the impulse is unaffected by the collision.

The proof is again a locus problem. After impact, what are the orientation and magnitude of the force of the light impulse? The same two conditions apply: (1) unchanging total quantity of force of the ray; (2) conservation of the parallel component of the force of the ray. Represent (1) by a circle about A. Represent (2) by appropriately spacing FED parallel to HB and AC. Combining our conditions gives BF as the representation of the unchanged magnitude of the force of the ray and its new orientation. We have taken the diagram for the tennis ball model and reinterpreted it as a diagram about forces and determinations. This is obvious, provided, first, that you attend to the very instant of impact; and, second, that you take the circle and lines to represent the quantity and determination of the force of motion of the ball, as they are instantaneously rearranged in the impact. Descartes' vocabulary of 'forces', 'tendencies' and determinations is already reading the diagram that way, and later correspondence supports this. In this reading, the conceptual distance between the tennis ball model and the impulse theory of light virtually disappears.

Let us now turn to the tennis ball model for the refraction of light

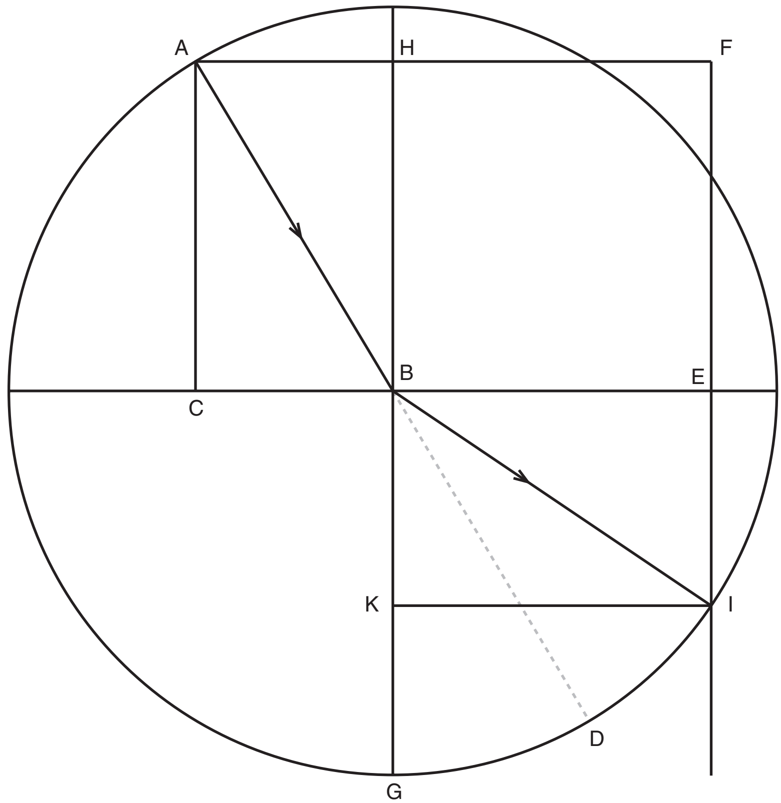


Figure 12.3

(Figure 12.3). Again consider a tennis ball struck along AB toward surface CBE. In this case the surface is a vanishingly thin cloth. The weight, shape and bulk of the ball are again neglected. It is taken to move without air resistance in empty geometrical space on either side of the cloth. In breaking through the cloth, the ball loses a certain fraction of its total quantity of force of motion, say one half. This fractional loss is independent of the angle of approach.[19] Again two conditions are applied to the motion of the ball. First, the new quantity of force of motion (one half the initial amount) is conserved during motion below the sheet. Second, the parallel component of the force of motion, the parallel determination, is unaffected by the encounter with the cloth. Descartes takes the breaking through the cloth as an analogue to a surface collision, in which the parallel component is unaffected. We draw a circle about point B. Assume the ball took time t to traverse AB prior to impact. After impact it has lost one half of its force of motion, and hence one half of its speed. It therefore must take $2t$ to traverse a distance equal to AB. It arrives somewhere on the circle after $2t$.[20]

Now, prior to impact the parallel determination 'caused' the body to move towards the right between lines AC and HBG.[21] But, after impact, the ball is taking 2*t* to move to the circumference of the circle, so its unchanged parallel determination has twice as much time in which to act to 'cause' the ball to move toward the right. Therefore set FEI parallel to HBG and AC, but make the distance between FEI and HBG twice as great as that between HBG and AC. At time 2*t* after impact the ball will be on the circle and on line FEI; that is, at point I, their intersection point below the cloth. The sine of the angle of incidence, AH, is to the sine of the angle of refraction, IK, as one is to two; that is, as the force in lower medium is to the force in upper medium – which ratio is constant for all angles of incidence.[22]

Now, as we did in the case of reflection, let us sketch a proof of the law of refraction in the case of a light ray and Descartes' dynamics (Figure 12.4). This will prove most instructive and consequential for our inquiry into how Descartes first constructed the law and how he subsequently came to design his dynamic rationale of the law.[23] Consider a ray incident upon refracting surface CBE. Let length AB represent the magnitude of the force of the light impulse. The *orientation* and *length* of AB represent the principal determination of the ray. The force of the ray is diminished by half in crossing the surface, so we must draw a semi-circle below the surface about B with a radius equal to one half of AB; that is condition one. We also know that the parallel determination of the force of the ray is unchanged in crossing the surface; that is condition two. The distance between AC and HBG represents that parallel determination. Therefore, we must set out line FEI parallel to the two former lines and with the distance between FEI and HBG equal to that between HBG and AC. Again the intersection of the lower semi-circle and line FEI gives the new *orientation* and *magnitude* of the force of the ray of light, BI and the law of sines follows.

The case of the light ray (Figure 12.4) requires manipulation of two unequal semi-circles. These directly represent the ratio of the force of light in the two media. In the tennis ball case (Figure 12.3) we went from ratio of forces to ratio of speeds and hence differential times to cross *equal* circles. But, in both cases at bottom we are attributing the same type of force and determination relations to the ball, and to the light ray, at the instant of impact.[24]

It is sometimes said Descartes fell into a contradiction, because in his theory of light, light rays move instantaneously through any medium, while in the tennis ball model we must deal with a ratio of finite speeds. We can now see that Descartes had no problem: one must distinguish the *speed* of propagation of a light ray, which is instantaneous, from the *magnitude* of its force of propagation, which can take any finite positive value. The *speed* of Descartes' tennis ball corresponds not to the speed of propagation of light but to the intensity of the force of its propagation.

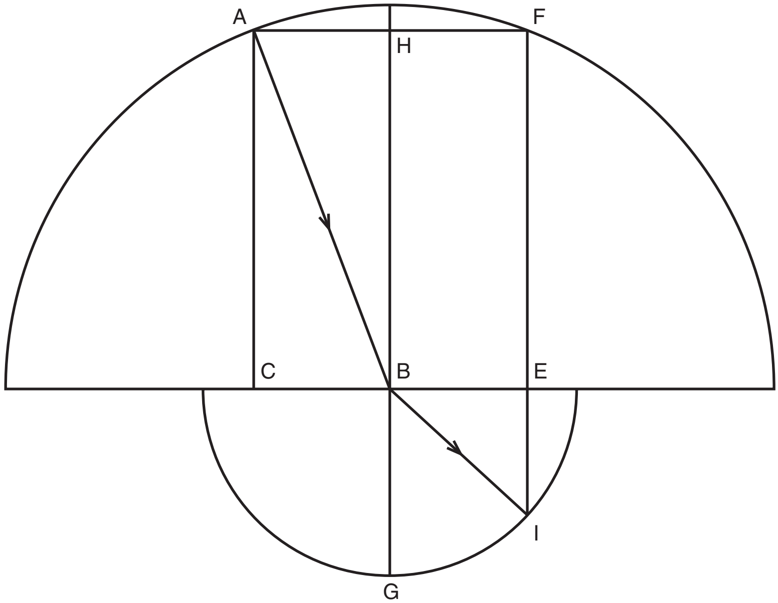


Figure 12.4

Descartes' dynamic premisses: demonstrative efficacy and empirical weakness

Our analysis thus far goes some way toward vindicating the plausibility and coherence of Descartes' attempted demonstrations. Having decided in 1633 not to publish his first system of natural philosophy, *Le Monde*, Descartes offered the public in 1637 the *Discours de la méthode* and its three supporting *Essais*. The *Dioptrique* therefore appeared without the full backing of Descartes' principles of dynamics and real theory of light. Yet, we have now seen that the proofs were set up in such a way that their dependence upon the dynamics and their pertinence to the real theory of light lurked between the lines, and hence could have been brought into the open in case of the eventual revelation of the full system. We have simply tried to read the proofs across a prior knowledge of the relevant contents of *Le Monde*. The dynamics of light which we can read out of *Le Monde* makes good sense of the core aspects of the optical proofs. Using Descartes' dynamic principles we can relate the tennis ball model back to the real theory of light, and hence acquits Descartes of the traditional charge that the variable speed of the tennis ball bears no analogy within the real theory of light. We have also seen that recent commentators are correct to interpret 'determination' as a coherent mechanical concept, denoting the directional magnitude of the force of motion. There are, however, definite limitations to this procedure of interpretive vindication, for even in our interpretation many problems surround Descartes' presentation, and the analysis of these problems is going to provide some signposts, both for the reconstruction of Descartes' route to the law of refraction and about its manner of 'demonstration'.

The difficulties with Descartes' theory of refraction arise from the very core of his presentation, from the two principal dynamic premisses used in deducing the law of refraction. One may formulate his premisses as follows.

(1) For any two optical media, the quantity of the force of light in the upper 'incident' medium bears to the quantity of the force of light in the lower 'refracting' medium a constant ratio, characteristic of the two media and independent of the path of propagation, or

$$\frac{|Fi|}{|Fr|} = \text{const}$$

where $|Fi|$ is the quantity of force of light in the upper medium, and $|Fr|$ the quantity of the force of light in the lower medium.

(2) The component of the determination of the force of light parallel to the refracting surface is unaffected by the refraction of the ray, or

$$|Fi| \sin i = |Fr| \sin r$$

Combining (1) and (2), we obtain, following Descartes[25]

$$\frac{\sin i}{\sin r} = \frac{|Fr|}{|Fi|} = \frac{1}{\text{const}}$$

We have seen that these premisses can be grounded in Descartes' dynamics; that they mesh with his real theory of light as an instantaneously transmitted mechanical impulse; and that they allow a plausible deduction of the law of refraction in an idealised case, in which a vanishingly thin sheet, separating two void spaces, refracts an incident tennis ball, which for all practical purposes has been reduced to a point localisation of an instantaneously exerted quantity and directional magnitude of force. But although the premisses work well in this limited and idealised context, as soon as one considers more complex and less idealised cases, they begin to reveal certain problems of empirical plausibility and logical consistency.

To put the matter in a nutshell, when one considers real space-filling media, Descartes' first dynamic assumption – path-independent ratio of the force of light – seems to entail that optical media are isotropic, while the second dynamic assumption – conservation of the parallel determination – seems to entail that they are not. We are about to see that Descartes was aware of some of the difficulties consequent upon so construing the premisses, and that he tried both to finesse and ignore them while holding firm to the premisses themselves. His determined investment in premisses which permit derivation of the law of refraction, yet which are so empirically questionable in themselves, can provide us with clues about how the law was originally discovered and when and why the premisses were devised. We shall first look at these difficulties in an abstract and slightly 'whiggish' fashion, and then show how they manifested themselves in Descartes' articulation of his theory of refraction.[26]

At first sight Descartes' assumption (1) would seem to entail that optical media are isotropic, for the force ratio depends only upon the nature of the media, and is independent of the incident and refracted paths of the tennis ball or light ray. The most superficial examination of assumption (2), however, shows that this must be an oversimplification. Assumption (2) maintains the conservation of the parallel component of the principal determination before and after refraction, and hence it entails that in refraction all dynamic changes affecting the ball or the ray in fact come about through variation in the normal component of the incident principal determination. Of course, Descartes' proofs assign no quantitative or geometrically constructive role to the comportment of the normal component: the locus problems are solved using only the absolute quantities of force and the parallel components of the determination (laid off by lines normal to the refracting surface). Clearly, then, assumption (2) entails that Descartes' implied sense of 'isotropic' must differ from ours. His 'isotropic' media effect changes in the normal components of the determination of the incident ray which are complicated functions of the angle of incidence, while they leave the parallel component untouched.

Assumption (2), which raises difficulties for the isotropic character of optical media suggested by assumption (1), also generates some empirical implausibilities when considered on its own. While one can perhaps intuitively grasp how a vanishingly thin sheet might affect only the normal component of the incident determination, is this really plausible in the case of real space filling media? In such media, collision with the surface may well affect only the normal determination; but what about the ball's or ray's subsequent penetration of a finite thickness of the medium? Would not the ball or ray now encounter altered conditions of motion (or of tendency to motion) in the direction parallel to the surface? If (1) really entails that media are isotropic in some sense, then the parallel component must be affected in precisely the same way as the normal component. So, depending upon how one views Descartes' implied notion of isotropic media, his assumptions are either contradictory or simply wildly implausible in an empirical sense: either (1) entails our notion of isotropic media while (2) denies it; or (1) entails path-dependent variations in the normal component, which are then most implausibly denied to the parallel component by (2) in the case of space filling media.

Returning to the *Dioptrique*, one finds that Descartes began to encounter difficulties reflective of these deeper problems as soon as he moved beyond the case of the thin sheet separating two void spaces. When he turns to space filling media, Descartes harks back to Figure 12.3 in which he now takes CBE to be the upper surface of a volume of water. He argues that if the tennis ball loses, as before, one third of its force of motion in encountering the surface, then the derivation of the new refracted principal determination will also follow as before and the ball will be refracted toward I:

> First of all, it is certain that the surface of the water must deflect it toward there in the same way as did the cloth, seeing that it takes from the ball the same amount of its force, and that it is opposed to it in the same direction.[27]

So, as one expects, refraction is still held to be an interface phenomenon, the new principal determination being set at the instant the ball encounters the surface, by the alteration of the quantity of force of motion, conjoined with the conservation of the incident parallel determination. It makes no difference, Descartes next argues, that the ball, after refraction, passes through a real, dense volume filling medium, for the medium is isotropic in the sense that *it offers the same resistance to the passage of the ball, regardless of the angle of path 'set' by the refraction at the interface.*

> Then, as for the rest of the body of water that fills all the space between B and I, although it may resist the ball more or less than did the air that we assumed to be there before, this is not to say that because of this it must deflect it more or less: for it can open in order to permit it passage, just as easily in one direction as in another, at least if we always assume, as we do, that neither the heaviness or lightness of this ball, nor its bulk, nor its shape, nor any other such foreign causes changes its course.[28]

Descartes apparently expects readers to accept that by appealing to the isotropic character of the medium, he can thus separate the setting of the refracted determination at the moment of encountering the interface, from any mechanical effect the ball might undergo in passing through a finite thickness of the medium.

Descartes' strategy here seems to be to preserve at all costs the locus construction in Figure 12.3, centring on the circle AIG and the lines AC, HB and FE, the representations of his two central assumptions. He fails to explain why the parallel component should be conserved during the passage of a finite thickness of the medium, and simply tries to persuade us that since media are isotropic in the Cartesian sense, whatever determination is set at the interface will be preserved within the medium. It was quite feasible for a contemporary reader to question Descartes' implied concept of isotropic media as both ad hoc and empirically implausible. In 1640 Père Bourdin explicitly questioned why the ball, in entering the water, is not retarded in moving from left to right, just as it is retarded in moving from high to low. Descartes' less than edifying response was that he had already dealt with this problem in the *Dioptrique* when he considered refraction through a thin sheet (sic):

> in order to show that it does not occur in the depth of the water, but only on its surface; and . . . that it is necessary to consider only the determination of the ball [*ver quel cote se determine la bale*] upon entering the water, because afterwards, whatever resistance the water exerts upon it will not change its determination.[29]

This adds virtually nothing to the argument in the *Dioptrique*, and it in no way justifies Descartes' premisses or answers Bourdin's penetrating query. For what is at issue is how can it possibly be, given Descartes' premisses, that refraction does in fact only occur at the interface. Descartes' answer amounts to the claim that, since in fact refraction occurs only at the interface, his premisses explaining refraction must surely be adequate to that fact, as indeed they are, if only one conceptually separates consideration of the causes of refraction at the interface from the effect upon the ray of the isotropic character of any finite thickness of the medium. Hence, we are forced to the following conclusion: the cash value of these manoeuvrings can only have been the staunch defence of the premisses as such, and of the construction and demonstration which they ground.[30]

The difficulties posed by the two premisses emerge more subtly when Descartes deals in the *Dioptrique* with the case of refraction toward the normal. In the tennis ball model the racket is taken to strike the ball again at the moment of incidence, thus increasing its speed, or quantity of force of motion, in a given ratio to the incident speed.[31] Commentators have often noted the sheer ad hocness of this strategy, as well as the even more damaging point that in the real theory of light there is virtually no analogue for this providentially adjusted stroke of the racket. But it is less the ad hocness of the argument which interests us here, than the deeper conceptual embarrassments of which it is merely a symptom. Note that according to Descartes' theory the second stroke of the racket must act in the normal direction, for there can be no alteration in the parallel component of the determination. This means that depending upon the angle of incidence, the racket acts in the normal direction to increase the normal component in such a manner that, as a consequence, the overall absolute quantity of force of motion is increased in just the prescribed ratio. Descartes could hardly have failed to realise this, since it is an immediate consequence of the explicitly stated portion of his theory. However, he astutely avoided a clear indication that the racket must act in the normal direction (much less that its normal action is a function of the angle of incidence).

> But let us make yet another assumption here, and consider that the ball, having been first of all impelled from A toward B, is impelled again, once it is at point B, by the racket CBE which augments the force of its movement by for instance one-third, so that afterwards it can make as much headway in two moments as it previously made in three. This will have the same effect as if the ball were to meet, at point B, a body of such a nature that it could pass through the surface CBE one-third again more easily than through the air.[32]

Descartes' form of words is designed so as not to reveal to the reader the deeper consequences of the theory. His concern was well justified, because, of course, these consequences attach as well to the previous case of refraction away from the normal. Although the metaphor of penetrating a thin sheet tends to hide the relevant dynamic considerations, it remains the case that the *loss* of force of motion in a fixed ratio to the incident force of motion can only be accomplished on Descartes' premisses through a path-dependent decrease in the normal component of the incident determination. Descartes was and remained unwilling to bring these consequences into the open, for they threatened the plausibility of his central assumptions, and their presumed ties to his larger views on dynamics and the real theory of light. By what Cartesian mechanical means, after all, is such a path-dependent variation in a normal component to be effected, in the case of the decrease *or* increase of the incident force of motion? And if such a path-dependent variation in a normal component must occur, why then, to resume the earlier critique, does this not also occur in the parallel direction in the case of penetration of a finite thickness of the 'isotropic' refracting medium?

In sum, Descartes' two dynamic premisses permitted a plausible deduction of the law of refraction, but they generated what seemed to some of his readers, and arguably to Descartes himself, to be crippling difficulties. His theory deals poorly with volume filling media, with refractions towards the normal, and more generally with the question of how it happens that the alteration in the normal determination is variable, depending upon the angle of incidence. Indeed, virtually the only strength of Descartes' central assumptions resides in their pleasing ability to rationalise the geometrical steps in his construction of the path of a refracted ray or ball. Descartes was willing to try to ride out likely accusations that the premisses are empirically implausible, dynamically ad hoc, and in some interpretations, logically inconsistent, because the premisses provided elegant and more or less convincing rationalisations for the geometrical moves in his demonstration. All this suggests that Descartes did not obtain his premisses through a deep inquiry into the conceptual and empirical requirements of a mechanical theory of the propagation and refraction of light. It seems more plausible to associate the premisses closely with the very geometry of the diagrams in which Descartes depicts and constructs the paths of refracted rays. The issue then turns on whether the premisses are post facto glosses of geometrical constructions arrived at in some other way; or whether the diagrams themselves were invented to illustrate previously held mechanical principles concerning the behaviour of light. In the following sections it will be suggested that the former hypothesis is the more likely. In particular it will be argued, first, that Descartes probably discovered the law of refraction independently of any mechanical assumptions, although he held a number of unsystematised and abortive ideas about the mechanics of light as early as 1620; and, second, that it was the geometrical diagrams expressing his newly found law which suggested to him the precise form and content of his two dynamic premisses and their mode of relation in explaining refraction.

Descartes' route to the law of refraction, 1619–27

In this section we turn to the discovery of the law of refraction. As indicated above, our unearthing of the dynamic framework of the optical proofs will ultimately aid our detective work.

The Mydorge letter of 1626/27

Thomas Harriot discovered the law in exact form around 1598 and Willebrord Snel, who died in 1626, discovered it sometime after 1620.[33] Descartes, working with Claude Mydorge, discovered it in 1626/27. The chief document supporting this conclusion is a letter from Mydorge to Mersenne.[34] It is well known to students of seventeenth-century optics, but I suggest that it has not yet been properly understood. That depends upon its dating, and the dating depends upon its content.

Mydorge's first claim is that if he is 'given the inclination and refraction of any one ray at the surface of any refracting medium', he can 'find the refraction of any other ray incident on the same surface'.[35] This is Mydorge's procedure (Figure 12.5): ray ZE is refracted at surface AEB, along EX. Draw a semi-circle above AEB cutting the ray at F. Draw FI parallel to the surface. From I, where FI intersects the semi-circle, drop IG perpendicular to the surface until it cuts the refracted ray at G. Then with radius EG draw another semi-circle about E, this time below the surface. This figure now permits the construction of the refracted path of any other incident ray, say HE. Draw HM parallel to the surface cutting the upper semi-circle at M. Drop MN normal to the surface until it meets the lower semi-circle. Connect E and N, then EN is the refracted ray.[36]

Mydorge observes that the law is given here as a law of cosecants. That is, taking the first ray

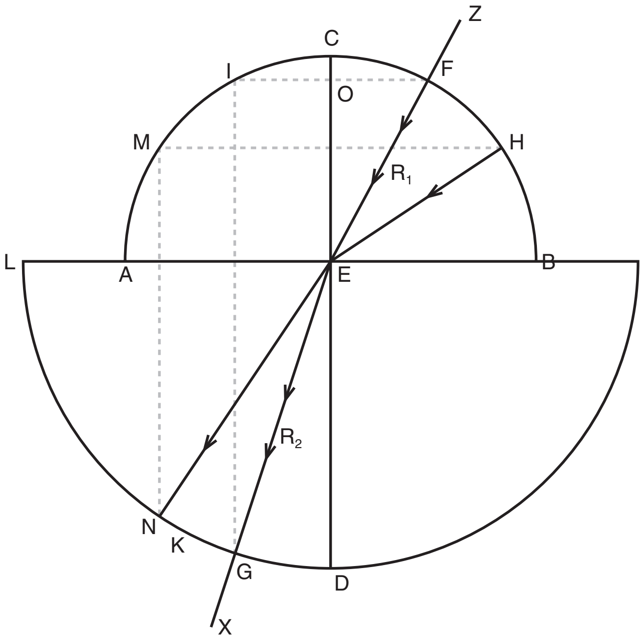


Figure 12.5

$$\frac{\text{cosec } i}{\text{cosec } r} = \frac{\text{R1/OF}}{\text{R2/OI}}$$

since OF = OI, the cosecants are as the radius of the upper semi-circle is to the radius of the lower semi-circle.[37] Let us call this the 'cosecants' or 'unequal radii' form of the law of refraction, compared to Descartes' *Dioptrique* form, which we shall call the 'sine' form or 'equal radius' form. We have seen this diagram before – it is identical to our Figure 12.4 for refraction using Descartes' theory of light as an instantaneous impulse. Mydorge uses two conditions to calculate the refracted ray. They are the same conditions that Descartes uses in his theory of light. The difference is that Mydorge states them only as rules of geometrical construction, while Descartes also gives them a dynamic rationale. The two conditions of course are:

1 the constant ratio of the radii of the upper and lower semi-circles for all angles of incidence. This, in Descartes' theory, becomes the path-independent constant ratio of force of light in the two media.
2 The equality of lines FO, OI, the parallel component of the line representing the ray. This later becomes the conservation of the parallel determination of the ray.

Note that Mydorge's figure gives a clearer picture of Descartes' two assumptions than does Descartes' one circle diagram (Figure 12.3) in the

Dioptrique. Why is this so? And why did Descartes invoke tennis balls in actual translation? Before we can find out, we must date the *material* in the letter.

Lens theory and the date of the material in Mydorge's letter

Descartes' earliest recorded statement of the *sine* law of refraction dates from a report to Isaac Beeckman in October 1628.[38] Descartes consistently identified 1626/7 as the crucial period for his optical studies.[39] He collaborated with Mydorge in that period, and Mydorge credited Descartes with the discovery of the law.[40] De Waard dated this letter from 1626, but that was merely a conjecture based on this collateral evidence.[41] Costabel, Shea and others date the letter from 1631 at the earliest.[42] But evidence in the letter concerning the presentation of the law and the development of lens theory, *strongly* suggests this *material* is from 1626/7, and is contemporary with the initial construction of the law and first articulation of lens theory.

After presenting the cosecant form of the law, Mydorge outlines a theory of lenses clearly antecedent to the theory of lenses offered in the *Dioptrique*. The key difference is that Mydorge does not initially use the sine law in constructing lens theory. Rather, starting with the cosecant form of the law, he only strikes a sine formulation in the course of his opening analysis of the anaclastic problem: it is a simple matter of adding a few lines.[43] He does not seem to know the sine form before that constructive manoeuvre. *Then* he deploys the sine form in the following synthetic demonstrations.[44]

Moreover, Descartes own synthetic lens theory demonstrations in the *Dioptrique* differ from those of Mydorge in another historically revealing way. Mydorge had set up the sines of the angles of incidence and refraction by reference to a semi-circle on one side of the interface.[45] In the *Dioptrique*, as we have seen, Descartes directly relates the sines to their respective rays.[46] Isaac Beeckman seems to have been the author of Descartes' more 'natural' representation of the sines. In October 1628 Descartes asked Beeckman to prove the refractive properties Descartes claimed for the hyperbola. Beeckman's proof is geometrically identical to Descartes' figure in the *Dioptrique* and was 'approved' by Descartes.[47] At the same time Descartes showed Beeckman an elegant proof for the ellipse case.[48] However, he did not use that proof in the *Dioptrique*, probably because the sines of incidence and refraction are not related to their respective rays in the obvious way Beeckman achieved for the plano-hyperbolic case.[49]

I conclude that in the *Dioptrique* Descartes used Beeckman's more 'natural' representation of the sines in both cases, ellipse and hyperbola, thus rejecting his own elegant ellipse proof and Mydorge's early 'one-sided' representation of the sines. The Mydorge letter therefore contains

Mydorge and Descartes' *earliest lens theory*, and arguably *their first form of the law*, the cosecant form. The *material in the letter*, if not the artefact itself, predates October 1628, certainly predates composition of the *Dioptrique* and very plausibly is as early as 1626/7 – but not earlier as we shall soon see. So this dating points to the cosecant form of the law as the first form Mydorge and Descartes possessed. And this, it transpires, is the key to reconstructing how they obtained it, because the other independent discoverers first obtained it in the same *unequal radius form*.

Traditional geometrical optics and the discovery of the cosecant form of the law

To reconstruct how Descartes found the law, let us first follow Johannes Lohne's important analysis of how Thomas Harriot discovered the law, because, as we shall see, Mydorge's letter provides evidence for an identical path of discovery.

One obvious phenomenological expression of the behaviour of refracted rays is the displacement of images of objects viewed under refracting media. Traditional geometrical optics had a rule for constructing the image locations of such sources. Lohne supposed that Harriot attempted to discover a general relation between the incident and refracted rays using the image rule; and that the *cosecant* form of the law resulted from this strategy of research.

The traditional image placement rule ran as follows (see Figure 12.6):

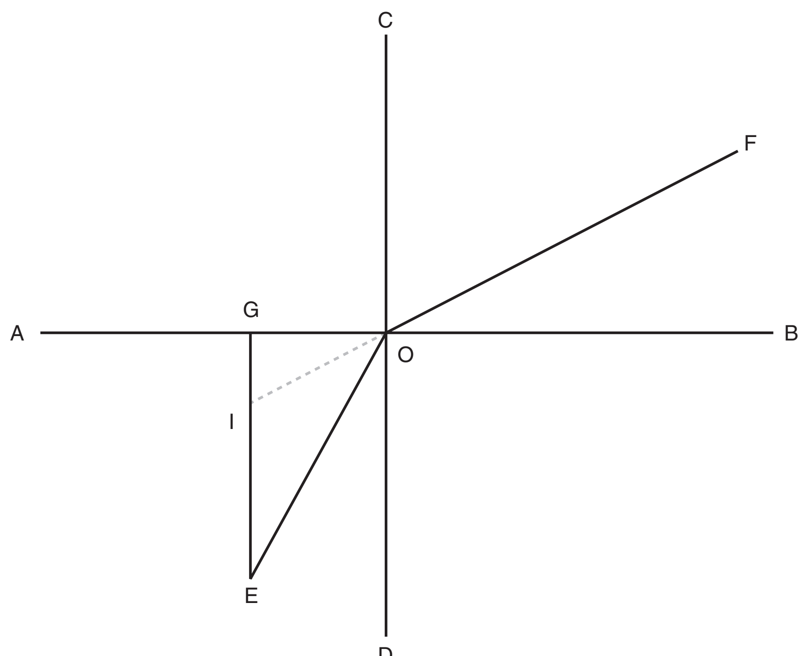


Figure 12.6

AB is a refracting interface; CD the normal to AB at O, the point of incidence. E is a point source emitting ray EO, refracted at O to the eye at F. Experience teaches that E will not appear at E. Where does it *seem* to appear? The rule says that it will appear at I, which is the intersection point between the refracted ray FO drawn back into the first medium, and EG, which is the normal to the surface from E.[50]

Harriot used this rule in conjunction with observations made with a disk refractometer half immersed in water. Taking source points at 10° intervals around the lower circumference of the disk, he observed the corresponding angles of refraction. He then constructed the image places for the source points, by applying the image rule. With the source points located around the circumference of the disk, he found the calculated image places lie roughly on a smaller, concentric circle. If you suspect the plot is really a circle, a little trigonometric analysis gives you the cosecant form of the law. Harriot's key diagram (Figure 12.7) is indistinguishable from Mydorge's diagram.[51]

It is important to note that Mydorge and Descartes need not even have made *any* such observations. They could have used Witelo's rather cooked data for water/air and glass/air interfaces. I have followed calculations originally provided by Bossha and found that this data is good enough to give a strong suggestion of a semi-circular plot when used in Harriot's manner.[52] Trigonometricians of the calibre of Snel, Mydorge and Descartes need only have suspected the circular plot to seize upon it and explore it further. Mydorge's diagram arguably has the form it does because he and Descartes proceeded in the same way as

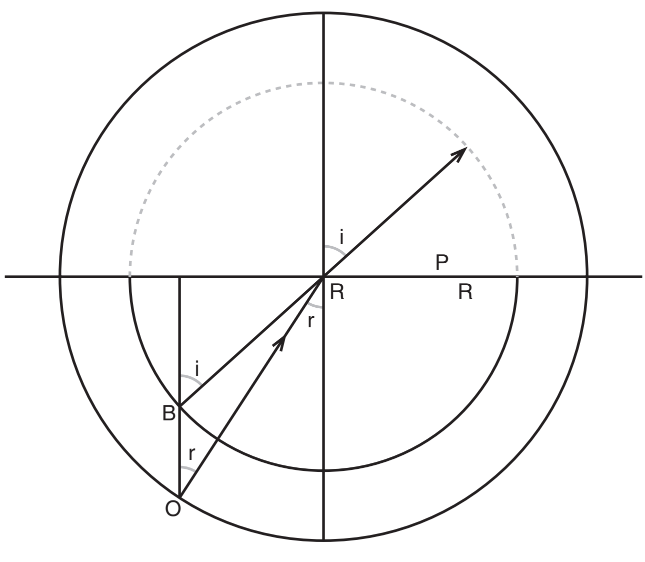


Figure 12.7

Harriot (and Snel), leading to the same cosecant form of the law. Mydorge probably took a diagram like Harriot's and then flipped the smaller semi-circle up above the surface to create the path predicting device in his letter.

In sum, strong evidence exists that the law was constructed by traditional optical means, using data and concepts familiar to skilled students of geometrical optics. This account involves nothing about the dynamics of light or of tennis balls. What then is the relation between the cosecant form of the law and Descartes' two dynamic assumptions? Did Descartes perhaps have the two assumptions prior to 1626/7, and, if he did, is it still possible that despite our reconstruction, he arrived at the law by deducing the cosecant form from the assumptions? While that is, of course, logically possible, it is not supported by the existing evidence, as we shall learn in detail in the following section.

The dynamic premisses for the deduction of the sine law of refraction: their pre-history and history 1618–29

In this section we shall see that by the early 1620s Descartes did possess some intriguing views about the dynamics of light, but that these conceptions could not have directed him to the law. Indeed, they constituted an obstacle to his ever finding it. This will prompt the firm conclusion that the two dynamic premisses were initially seen in, and modelled upon, the Mydorge diagram, when Descartes saw that the geometry of that diagram clarified and modified his earlier, inefficacious, dynamic notions. We can unpack all of this by examining the main alternative conjecture as to Descartes' route to the law of refraction, that owing to A.I. Sabra. The evidence that dismisses his explanation further buttresses my version of the story.

Sabra's conjectural discovery path

Sabra holds that Descartes could have discovered the sine law in the very way he deduces it in the *Dioptrique*. Suppose Descartes possessed the two key assumptions used in this proof; he could then have discovered the law by deduction.[53] We have already foreshadowed Sabra's argument.[54] The first assumption is that the ratio of the force of light in two media is a constant for all angles of incidence:

$$\frac{|Fi|}{|Fr|} = \text{const}$$

The second assumption is that the component of the force of light parallel to the refracting surface is unchanged by refraction:

$$|Fi| \sin i = |Fr| \sin r$$

Combining (1) and (2) we get the sine law:

$$\frac{\sin i}{\sin r} = \frac{|Fr|}{|Fi|} = \frac{1}{\text{const}}$$

The essential question is, did Descartes have the two assumptions before the Mydorge letter? Sabra seizes on an early fragment of Descartes, dating from 1620, which, he argues, implies possession of both assumptions. This means Descartes could have deduced the law any time from about 1620. The fragment reads in part:

> Because light can only be produced in matter, where there is more matter there it is more easily generated; therefore, it more easily penetrates a denser medium than a rarer one. Whence, it happens that refraction occurs in the rarer medium from the perpendicular, in the denser medium toward the perpendicular.[55]

For Sabra the first sentence *is* assumption 1: the force of light is as the density of the media – independently of path. Sabra then notes the sentence: 'whence refraction occurs toward the normal in the denser medium, and away from the normal in the rarer medium'. He asks, how can Descartes say *that* unless he also has the second assumption? And, of course, given the two assumptions, Descartes could have deduced the law of refraction.[56] Sabra is thinking of a diagram very much like the Mydorge diagram, which, of course, neatly represents these assumptions.

Nevertheless, we hold that Sabra is mistaken: Descartes' first sentence does not contain or entail assumption (1). Rather Descartes is assuming that the normal component of the force of light is increased in a denser medium. In other words in 1620 he holds:

$$\frac{F_i^{\perp}}{F_r^{\perp}} = \text{const. rather than } \frac{|Fi|}{|Fr|} = \text{const}$$

To establish this we have to consider first what Sabra ignores – Descartes' style of natural philosophising and doing optics circa 1620.

Descartes' 'Physico-Mathematicus'

In November 1618 Descartes met Isaac Beeckman and fell in with his dream of a natural philosophy that would be both corpuscular-mechanical and properly (rather than metaphorically) 'mathematical'. They termed this project 'physico-mathematics'. Although Descartes and Beeckman produced no convincing examples of this discipline, in one or two special cases it is clear that they thought they possessed real instances of it.

An example of this is one of Descartes' fragments from the period, the so-called 'the hydrostatics manuscript'.[57] Beeckman had asked Descartes to explain in 'physico-mathematical' terms some of Simon Stevin's hydrostatics. Stevin had demonstrated what is essentially a special case of the hydrostatic paradox by employing a rigorously Archimedean style of mathematical argument. He applied *reductio ad absurdum* arguments showing that conditions of static equilibrium obtain between specified macroscopic volumes and weights of water (and of notional solids of equal specific gravity). Descartes' attempted 'physico-mathematical' gloss of Stevin is a *bricolage* of ad hoc assertions about, and geometrical representations of, the corpuscular structure of fluids and the characteristic motions and tendencies to motion of their constituent particles. Descartes took this to be a promising piece of 'physico-mathematics', what with its geometrical representation of the tendencies to motion of the constituent corpuscles.

The 1620 optical fragment: a physico-mathematical reading of Kepler

Now let us return to the optical fragment of 1620. Sabra used only part of it. Examination of all of it shows that Descartes was studying Kepler's *Ad vitellionem paralipomena* (1604) and that his fragment is a 'physico-mathematical reading' of a set of texts and figures in Kepler's work. Descartes was reading Kepler the way he had read Stevin: seeking grist for the physico-mathematical mill, he attempted to elicit some physical theory from a set of compelling geometrical diagrams and texts for refraction presented by Kepler.

The most important claims in Descartes' fragment are (1) that the 'penetration' of light varies positively with the density of the medium; and (2) that consequently light is refracted toward the normal in the denser medium, and away from the normal in the rarer one. It is essential to realise that in the traditional optical literature there is no precedent for this sort of sketch physical theory of refraction. Earlier major authorities on optics, such as Alhazan, Witelo, Roger Bacon and Peckham, as well as contemporary ones such as Snel, had maintained in one fashion or another that media resist the passage of light in proportion to their densities, and that the path of motion normal to the refracting surface is the easiest or one of least resistance. From these premisses opticians contrived to conclude that a ray obliquely entering a denser medium, and hence meeting increased resistance at the interface, must be refracted in a path lying closer to the easiest, normal path; and that a ray obliquely entering a rarer medium, and hence meeting decreased resistance at the interface, must be refracted into a path lying farther from the easiest, normal path.[58] Various explications were offered in attempting to link these conclusions to the premisses. What one might term Kepler's 'official' qualitative theory of refraction, published in ch. 1 of *Ad vitellionem*, differed considerably from that of the Medieval and Renaissance perspectivists; but even he retained the stress on the denser medium weakening the incident light.[59]

It is quite obvious that Descartes' sketch theory of refraction rejects the central elements of the Medieval and official Keplerian theories of refraction. For example, refraction toward the normal in denser media in no way depends upon a weakening or obstructing of the incident light; quite the contrary, refraction toward the normal is said to depend directly upon the greater 'penetration' or 'generation' of light in denser media. *A fortiori*, there is no role for a compensating bending toward the easier, normal path, as in the Medieval theories, nor does Descartes envision that a weakened parallel component causes the bending toward the normal, as in Kepler's official theory. So Descartes certainly did not obtain his 1620 theory of refraction by reworking those of his predecessors. The conceptual resources upon which he was drawing are likely to have resided, if at all, in less obvious corners of the traditional optical literature. As suggested above, there is strong evidence that Descartes was reflecting upon certain parts of Kepler's work on refraction in *Ad vitellionem*. This line of investigation was initially prompted by the concluding portion of the 1620 fragment, not cited earlier, which discusses image places in the context of Kepler's new theory of vision. Examining the portions of *Ad vitellionem* which deal with refraction, while bearing in mind Descartes' 'physico-mathematical' interests, brought to light two sets of passages which do seem to have provided the starting point for his curious 1620 theory of refraction.

The first and most important passage occurs in ch. 4 of *Ad vitellionem*, where Kepler attempts to discover a simple law of refraction by means of an analysis of its putative physical causes. Kepler asserts that there are two fundamental physical factors which any adequate theory of refraction must take into account: the inclination of the incident rays, and the densities of the media. (These points are consistent with his 'official' theory of refraction, described above.) He offers a geometrical construction representing these factors (Figure 12.8). Take AG incident upon a basin of water. The density of water is said to be twice that of air, so Kepler lowers the bottom of the basin DE to LK so that the new basin contains 'as much matter in the rarer form of air as the old basin contained in the doubly dense form of water'. Kepler then extends AG to I and drops a normal from I to LK. Connecting M and G gives the refracted ray GM. Its construction involves the obliquity of incidence and densities of media.[60] Although Kepler then goes on to reject this construction on empirical grounds,[61] the question is, did this text speak to René Descartes, the 'physico-mathematician' and budding optician, and what did it say?

The first thing to notice is that Descartes' fragment and Kepler's text resemble one another in precisely those respects in which they are anomalous with regard to the traditional theories of refraction. Kepler's construction, like the Medieval theories and his own official theory, stresses the role of the greater density in bending rays towards the normal. But in his figure Kepler directly represents the greater density (by lowering bottom DE) and he then utilises that representation in an unmediated fashion to construct the refraction of the ray towards the normal. It is

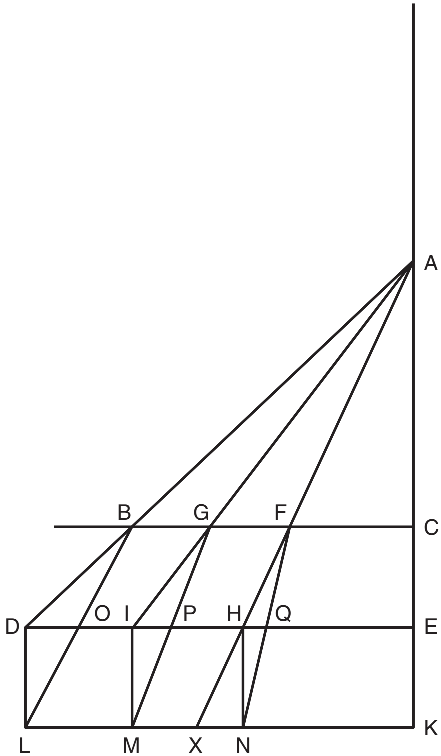


Figure 12.8

strongly implied that greater density is a direct cause of bending toward the normal. Kepler does not argue, as had the Medieval perspectivists, from greater density of the medium, to more resistance to the passage of light, and thence to a compensating bending towards the 'easier' normal path. Nor does he argue, as he had in his official theory, from greater density of the medium, to weakening of the parallel component of the motion of the light, and thence to bending towards the normal. Descartes' fragment is peculiar in precisely this same respect. There is no mention of a weakening of the light or of any of its components, nor of a compensating bending towards the normal. Instead, greater density is connected with greater 'generation'/'penetration', which apparently directly causes refraction toward the normal. Descartes' fragment would therefore appear to be based in some way upon Kepler's text and construction.

It is not difficult to see why Descartes, the aspiring 'physico-mathematician', would have been attracted to the non-traditional approach manifested in Kepler's text. Kepler was trying to penetrate beyond the mere phenomenon of refraction and to identify its physical causes; he wanted to represent geometrically the action of these causes and build the representations into a method of generating, by geometrical construction, the paths of refracted rays. Descartes, who had already attempted to identify and geometrically represent the true causes of the paradoxical statical behaviours of fluids, 'superficially' examined by Stevin, probably saw Kepler's construction as a promising step toward the physico-geometrisation of the problem of explaining refraction.[62]

This may explain Descartes' source and his motivation, but it does not yet elucidate the precise wording of his fragment. Here one has to be careful in teasing out the relationship between Descartes' fragment and Kepler's passage; for the fragment is not a simple verbal transcription of Kepler's construction technique (and verbal gloss), but rather an elaboration and explication of them. As we have seen, the two texts share the same anomalous posture vis-à-vis traditional theories of refraction. But within that broad similarity there resides an important residual difference. Kepler's construction technique does not focus upon, or work with, the parallel and normal components of the motion of the incident light or light ray. He directly represents the causally efficacious greater density of the lower medium and postulates a construction technique which uses that representation of density, and the obliquity of the incident ray, to manufacture a ray path bent towards the normal: the greater the obliquity of incidence and the farther the bottom DE has been lowered, the greater the resultant refraction towards the normal. In contrast, Descartes' fragment introduces the concept of 'generation'/'penetration' of light which varies with density. It is the increased or decreased 'penetration' (itself the product of greater or lesser density) which causes refraction towards or away from the normal. Descartes, unlike Kepler, wishes to characterise the properties of the light or light ray itself and to insert the characterisation between the talk of 'density' and of 'refraction'.

Why should Descartes have been led to view the Kepler diagram in these terms? Why mention 'penetration'/'generation' at all? Why not just say that greater or lesser density causes refraction towards or away from the normal? The answer would seem to be that Descartes, in interpreting Kepler's passage, was reintroducing quite customary questions about the comportment of the parallel and normal components of the motion of the incident light, or of the ray that represents it. Kepler, in other contexts in which he deals with refraction (and reflection), typically considers the comportment of these components, even though he does not always deduce changes in direction of light by (re-)composing altered components of its motion.[63] Descartes' contention that the 'penetration' of light varies with the density of the medium makes sense as a reading of Kepler's text, provided one takes Descartes to be thinking in terms of the comportment of the parallel and normal components of the motion of the incident light or of the incident ray. When approached in this way, Kepler's diagram and construction technique would be taken as saying that the denser medium has the effect of increasing one or both of these components, hence causing refraction toward the normal.

Only a little reflection is required to see that this in turn boils down to the claim that the normal component of the motion of the incident light increases upon entering a denser medium, while the parallel component can remain constant, increase in appropriate proportion, or even decrease.

The literal text of Descartes' optical fragment is therefore to be explained as follows. Descartes was pursuing the central idea of Kepler's passage, the direct causal role of greater or lesser density in bending light to or from the normal. But Descartes translated that physico-mathematical insight into the customary mode of discourse about the parallel and normal components of the motion of light or of light rays, and so produced his proposition about 'penetration' varying with density. Hence, when Descartes writes of the 'penetration'/'generation' of light being directly related to the density of the medium, he is envisioning the behaviour of the normal components of incident light rays. The magnitude of these components (the 'penetration') varies with the density of the medium. Increase in the normal component (with conservation or appropriate alteration in the parallel component) will bend the refracted ray toward the normal; decrease in the normal component (with conservation or appropriate alteration in the parallel component) will bend the ray away from the normal.[64] This then also explains the entailment between the first and second sentences of the fragment, claimed by Descartes and discerned by Sabra: Descartes can say that greater or lesser 'penetration' causes refraction towards or away from the normal, because he identifies greater/lesser 'penetration' with increase/decrease in the normal component, which can be represented in ray diagrams and used in the construction of refractions towards/away from the normal.

This reading of Descartes' fragment can be confirmed by looking at a second set of passages in *Ad vitellionem* which conditioned his thinking about the 'physico-mathematics' of refraction. Descartes' fragment, quoted above, continues: 'Moreover the greatest refraction of all should be in the densest medium of all'.[65] In his analysis of the fragment, Sabra did not cite or discuss this remark; yet, it is of vital importance in understanding Descartes as a 'physico-mathematical' reader-interpreter of *Ad vitellionem*. As it happens, in *Ad vitellionem* Kepler twice considers the notion of 'the most dense medium possible', pointing out on both occasions that any ray entering such a medium will be refracted into the normal direction (see Figure 12.9).

> In the most dense medium of all refractions are performed toward the perpendiculars themselves, and are equal in respect of (all) inclinations.[66]

And,

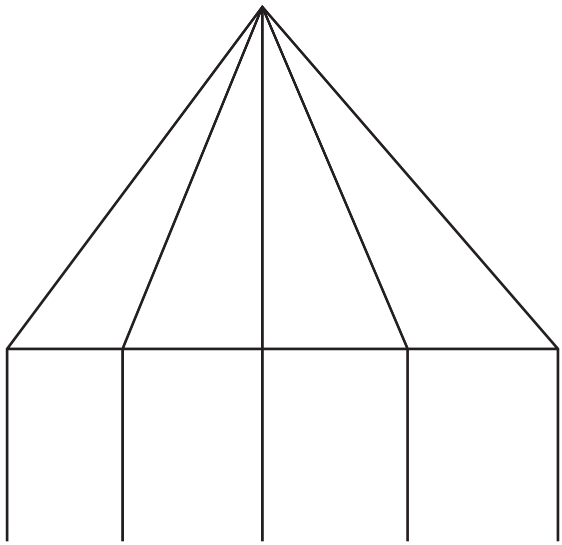


Figure 12.9

> If you should ponder what ought to occur in the most dense medium (or medium of infinite density), you would comprehend from the analogy of other media that, if there could be such a medium, it is necessary that all rays falling from one point onto the surface would be fully refracted, that is, after refraction they would coincide with the perpendicular itself.[67]

The context of these remarks is Kepler's official theory of refraction. The infinite density of the refracting medium destroys the parallel component of the motion of the light, leaving it only its normal component.

When Descartes echoes these passages in his fragment the context is not Kepler's official theory of refraction, but rather the first two sentences of his own 1620 text, as we have learned to read them. Clearly, Descartes intended to present the case of the 'most dense medium' as a limiting case of the general proposition that 'penetration varies with density and causes refraction to or from the normal'. That is, when a ray enters the most dense medium possible, the normal component is infinitely (or as Descartes probably would have had it, indefinitely) increased and the ray bent into the normal, regardless of whether the parallel component suffers a finite increase, decrease or merely stays the same. If Descartes drew his limiting case from Kepler, this lends extra weight to the claim that the first two sentences of the fragment constitute a 'physico-mathematical' reading of the other passage in *Ad vitellionem.*[68] In sum, Descartes connected two lines of speculation present in *Ad vitellionem* but not explicitly linked by Kepler: (1) the geometrical representation of the claim that 'the greater the density, the greater the refraction towards the normal', and (2) the claim that infinitely dense media would refract all incident rays into the normal. It was Descartes, not Kepler, who first related (2) to (1), using (2) to illustrate the limiting case of his own explicated version of (1) which related change in density to change in 'penetration' (normal component) to change in direction.

So, in 1620, Descartes embraced an assumption which would have hindered his ever deducing the sine law. He held that in two media the normal components of the force of light are in a constant ratio. Had he then assumed that the parallel components are constant, he would have got a law of tangents.[69] How then did Descartes ever devise his two assumptions – and, in particular, why did he ever decide that the constant force ratio applies to media, in a path-independent manner? All the evidence examined thus far suggests that a likely answer is this: Descartes only formulated his two dynamic assumptions *after* he had constructed the law in cosecant form, using traditional means – issuing in the Mydorge diagram. The Mydorge diagram – the cosecant form – gives you the two assumptions *if you are looking to read them out of the diagram.* And in 1626 Descartes, physico-mathematician, was very interested to read out of his ray diagram some mechanical theory explaining that diagram. In short, he did to the Mydorge diagram exactly what he had earlier done to diagrams in Stevin and Kepler: he took a geometrical picture of a macroscopic phenomenon and read out of it the underlying dynamic causes at the corpuscular level. Viewed through physico-mathematical spectacles, the Mydorge diagram was the locus where the two dynamic assumptions were forged and coordinated.

This reconstruction thus helps us understand why, after 1627, Descartes moved to a dynamic rationale for the law; and why that rationale took the form it did. Having been thwarted in his early attempt to arrive at the law of refraction by physico-mathematical analysis of its purported physical causes, Descartes would have seized upon the newly discovered and arguably correct cosecant form of the law of refraction. He decoded the Mydorge diagram as a message concerning the causes of refraction. This account also helps us deal with the problem of why Descartes embraced such problematical dynamic premisses for explaining refraction: why, as we noted earlier, he used dynamic premisses which simultaneously entail that optical media are and are not isotropic. The most likely answer is that, having formulated the premisses by inspecting the geometry of the already discovered cosecant form of the law of refraction, he accepted and defended these premisses because of their supreme value in grounding a deductive physical rationale for the law.[70]

The mechanical theory of light, 1620–8

Expository strategy and working distinctions

Thus far we have reconstructed how Descartes developed his two dynamic premisses while bracketing the question of what he actually took to be the nature of light. The reconstruction presupposed only that Descartes had thought of himself as a 'physico-mathematician', and that he had been committed in some sense to a mechanisation of optics. Beyond that, the discussion was intentionally non-committal about details: Descartes was said to have realised that the parallel component of the force or motion of the incident light is conserved before and after refraction, and that the quantity of the force or motion of the light varies with the density of the medium and is path-independent. Problems of exposition necessitated this strategy. For example, the place of the 1620 optical fragment in the development of the law of refraction can be assessed without having to linger over the ontological problems it poses and which we shall discuss below. Similarly, we shall see that evidence relating to Descartes' mechanistic theory of light in the period 1626–8 can only be decoded on the basis of a prima facie account of how and when the law of refraction was discovered. So, in this section we examine Descartes' commitment to a mechanistic theory of light between 1620 and 1628 with the goal of confirming and deepening the findings of the previous Section.

When investigating Descartes' commitments to mechanism and to a mechanistic optics, certain working categories need to be kept in mind. It is useful to distinguish between (1) fundamental ontological convictions in general, and (2) theories about the nature of light in particular. Furthermore, when considering (1) or (2), one needs to distinguish between (a) relatively articulated or systematised commitments or theories, and (b) relatively unarticulated commitments or theories. Combining these possibilities one obtains a set of four broad analytic categories.

(1a) A systematic corpuscular-mechanical ontology, such as is found in Descartes' two systematic treatises on the philosophy of nature, *Le Monde* (1629–33) and *Principia philosophiae* (1644). This involves an elaboration of the corpuscular-mechanical structure of matter, leading on to a theory of 'elements', a theory of the 'cosmological' structuring of matter, and an explicit doctrine concerning the laws of motion, collision and tendency to motion, or what we have termed Cartesian dynamics.

(1b) An unarticulated corpuscular-mechanical ontology, such as is found in Beeckman's *Journal*, or in Descartes' work prior to his commencement of *Le Monde*. This involves a general belief in corpuscular-mechanism and piecemeal appeals to it in formulating particular explanations, without a sustained attempt to organise or mediate between these particular applications. Certain consistencies might run through these applications and to that extent one might speak of an 'element theory', 'cosmology' or 'dynamics' implied in them; but, in general, the more that the theme of systematisation emerges and claims to control the applications, the more articulated and systematised the ontology can be judged to be.

(2a) An articulated corpuscular-mechanical theory of light, such as is found in the explanations of light in *Le Monde* or *Principia philosophiae*. In the broadest sense this would therefore involve the attempt to explain the true nature of light as part of the sort of system envisioned in (1a), in which the theory of light is articulated to the matter theory, cosmological setting and controlling principles of motion and dynamics.[71]

(2b) An unarticulated mechanical theory of light, such as we shall find in Descartes' optical work in 1626–8. This would involve a loose commitment to the mechanistic nature of light, based on piecemeal and unsystematised appeals to mechanistic causes, and to 'mechanistic principles' which have not taken the form of a systematised dynamics. This can involve a background belief in the corpuscular-mechanical character of matter and light.

One needs also to note that two broad options were open to Descartes in constructing a theory of light, whether under (2a) or (2b). Light could be taken to consist in the translation of pieces of matter or in mechanical impulses or tendencies to motion transmitted through media. Finally, under both (2a) and (2b) a theory of light could be elucidated or applied by means of explicit mechanical analogies. So, by the early 1630s Descartes had to hand his tennis ball model, which, as we have seen, was really offered under the tacit aegis of his (2a). Similarly we shall see that in the late 1620s he employed a balance beam model for the refraction of light, which is meant to clarify the version of (2b) which he then held.

Reprise – the optical fragment of 1620

Descartes' optical fragment of 1620 makes no direct reference to a corpuscular-mechanical ontology. Indeed, it appears to take a quasi-Aristotelian view of the nature of light, with Descartes writing of the 'generation' of light, although if taken literally this would imply light to be a substance, rather than the actualisation of a potential property of the medium, as Aristotle held. The generally Keplerian context of the fragment, which we established in the last Section, might suggest an underlying ontology of light as immaterial emanation. Yet, Descartes' apparent concern with quantifying the variation of 'penetration' (normal component) with density might also be evidence for an unarticulated theory of light as mechanical impulse or tendency to motion. For example, in the hydrostatics manuscript of 1619, Descartes had already explained gross weight as the product of summed corpuscular tendencies to (downward) motion, and he had analysed the 'weight-producing' normal components of those tendencies.[72]

However, teasing deep ontological commitments out of the optical fragment of 1620 may be slightly beside the point. Descartes seems less interested in ontology in general, or with the theory of light in particular, than with explaining refraction by relating density to 'generation/penetration' (magnitude of normal component), and expressing the relation geometrically. 'Physico-mathematics', as Descartes understood it, sought to combine corpuscular-mechanical ontology with genuine mathematicisation. Insofar as Descartes sought to explain refraction by mathematicising the density–penetration relation, he was comporting himself as a physico-mathematicus. The question of how (or even whether) the corpuscular-mechanical ontology applied was pushed to the periphery, as was any unequivocal commitment about the nature of light.

One possible explanation for Descartes' reticence about these issues may perhaps reside in his comparing Kepler's approach to refraction with Beeckman's corpuscular speculations about the phenomenon. To explain refraction Beeckman explicitly employed his corpuscular-mechanical ontology and a theory of light as the translation of light corpuscles. The macroscopic refraction of light results from a complex series of collisions between light corpuscles and the constituent particles of the refracting medium.[73] The explanation was qualitative and discursive, incapable of mathematical treatment, and, if we may judge by Descartes' eager appropriation of Kepler's texts, was thought unlikely to lead to the discovery of the law governing refraction. Encountering Kepler's physico-mathematical approach to refraction, Descartes may well have faced a choice: either to pursue Beeckmanian qualitative corpuscular-mechanical speculations about light and refraction, or to follow Kepler's attempt to identify and mathematicise the causes of refraction as a step towards the discovery of the law. In the latter case a corpuscular-mechanical explanation need not have been rejected in principle, but merely deferred until such time as the law of refraction might be discovered (and indeed this is the pattern our analysis has suggested thus far.)

Descartes' physico-mathematical encounter with Kepler's optics, recorded in the 1620 fragment, therefore probably affected his views about ontology in two ways. First, it discredited, for the time being, detailed corpuscular-mechanical stories about light, media, sources and the micro-mechanics of refraction, because these eluded and obstructed attempts at mathematisation. Second, at the level of even unarticulated theories of light, it exerted pressure away from explicit kinematic models and toward models involving no passage of any material entity. Beeckman's kinematic fantasies were avoided, but there were permitted models of light as mechanical impulse or as tendency to motion, or indeed as Keplerian immaterial substance, or even as Aristotelian actualisation of a potential property of the medium.[74] In this sense the 1620 fragment displays the boundaries within which Descartes' optical theorising would move during the next eight years. We shall now see that by 1626 he was firmly convinced of an unarticulated theory of light as instantaneously transmitted mechanical impulse or tendency to motion. Only in 1629/30, when he had begun to compose *Le Monde*, did Descartes attempt to devise an articulated corpuscular-mechanical theory of light (2a) within his emerging system of mechanical natural philosophy (1a). Likewise, it was apparently at this same time that he designed the tennis ball model for use in the *Dioptrique*. This was his only foray into the 'corpuscular'-kinematic modelling of refraction, and its use is quite circumscribed. On the one hand the tennis ball model is, after all, only a model for the corpuscular-mechanical theory of light as tendency to motion, and, on the other hand, the model itself is essentially premissed on the principles of his dynamics of instantaneously exerted forces and determinations, as we have seen.[75]

Light as an instantaneously transmitted mechanical impulse, 1626–8

Whatever the ambiguities of the 1620 fragment on the issue of the nature of light, one can be reasonably certain that by 1626 Descartes had opted for an unarticulated theory of light as mechanical impulse or tendency to motion, transmitted instantaneously through corpuscular media, though the microstructures of those media were not as yet a matter of concern, for the very reasons we have just canvassed. The main evidence on this point comes from parts of Descartes' *Regulae ad directionem ingenii* which he wrote in Paris between 1626 and 1628, after the discovery of the law of refraction, discussed in this section, as well as from discussions he held with Beeckman in 1628, discussed in the next section.

Limitations of space prevent a full discussion of the relevant portions of the *Regulae*, but the key point for our concerns here is that a theory of light as an instantaneously transmitted mechanical impulse plays a central role in and between the lines of the latter portion of the text, written in Paris between 1626 and 1628. I have argued elsewhere that the *Regulae* really consist in three main textual strata, written at different times between 1619 and 1628 with rather different aims in view.[76] The first stratum, consisting in a portion of Rule 4, is the remnant of a treatise which Descartes planned to compose in mid-1619 on the subject of 'universal mathematics'. Descartes conceived of this 'discipline' in mid-1619, viewing it as some sort of synthesis of his physico-mathematical project and his more purely mathematical researches, in particular his recent work in the generalisation of analytical procedures applied to classes of geometrical and algebraic problems. Universal mathematics was supposed to embody general analytical methods applicable to all genuinely mathematical fields, whether pure or physico-mathematical. It was more an enthusiastic post-adolescent dream than a practical reality. Descartes overestimated the generality and power of his analytical findings, and, as has been seen, his physico-mathematics was itself a loose assemblage of piecemeal and often quite tendentious initiatives. These difficulties most likely did not become clear to Descartes at the time, for by November 1619 his horizons widened even farther. The half-baked project of universal mathematics was superseded by and encysted within the main lines of his method, the dream of a general analytical machinery suitable for all rational disciplines, mathematical or not. I have shown that Descartes' constructed his doctrine of method by analogically extending concepts embedded in his none too efficacious discourse about universal mathematics. This was done in the winter of 1619–20, the results being recorded in the second stratum in the *Regulae*, Rules 1 to 3, part of 4, and 5 to 11, excluding some material in Rule 8.[77]

With his apparently effective method in hand, Descartes arrived back in Paris in 1625 and there was led into the composition of the third and final stratum of the *Regulae*. As I have established elsewhere, Descartes' *Regulae* project, under the influence of Marin Mersenne, now took the form of returning to the universal mathematics of 1619, which he would now attempt to construct in detail, by expanding and extending his 1619/20 text on method, that is, roughly Rules 1 to 11 of the *Regulae*. Universal mathematics would appear to grow out of the doctrine of method. The shift from the second to third stratum in the *Regulae* can be located inside the present text of Rule 8, and leads immediately to the methodological tale of how the anaclastic problem can be solved on the basis of the discovery of the law of refraction. This reinforces a dating for the third stratum of the *Regulae* after 1626/7 and prior to 1629. In order to underwrite universal mathematics, Descartes, in Rules 12 to 14, sketched the outline of a mechanistic theory of nervous function and perception.[78] The key point in the present context is that a mechanistic theory of light as instantaneously transmitted impulse underlay this enterprise, along with a 'mechanisation' of Kepler's new theory of vision.[79]

Light as mechanical impulse and the explanation of the law of refraction 1626–8 – the balance beam model

The theory of light as an instantaneously transmitted mechanical impulse, unarticulated as it was in 1626–8, would still have been sufficient to provide the conceptual framework for Descartes' 'physico-mathematical' reading of the Mydorge diagram, as discussed earlier. Descartes, *physico-mathematicus*, operating with an unarticulated theory of light as mechanical impulse, could have read the Mydorge diagram as giving evidence for the true physical premisses necessary for the demonstration of the law of refraction, premisses which corrected and reformed the ideas about density and penetration (normal component) evident in the 1620 fragment. (1) A light impulse, or ray, has a force, strength, or perhaps (retaining the language of 1620) a 'penetration', which varies when the impulse passes from one medium to another. For a given pair of media the ratio of these forces or 'penetrations' is constant and independent of the angle of incidence. (2) The force or 'penetration' of an impulse or ray may also be considered directionally, in the usual terms of components parallel and normal to the refracting surface. The force or penetration of the ray or impulse acting parallel to the surface must be unaffected by the refraction. This, of course, is a 'rational reconstruction' of how Descartes might have interpreted the Mydorge diagram, using a theory of light as mechanical impulse in the interests of designing a 'physico-mathematical' explanation of the new law. This rational reconstruction fills up the interpretive and evidential void left at the common terminus of several lines of textual and contextual reconstruction. There is, however, a very remarkable piece of evidence, dating from 1628, which we are now finally in a position to examine, and which shows Descartes striving to elucidate how the theory of light as mechanical impulse could be used in the demonstration of the law of refraction. Although it does not record Descartes' initial 'physico-mathematical' reading of the Mydorge diagram, it is arguably a product of research and reflection which followed very closely upon that event.

In the autumn of 1628 Descartes paid a short visit to the Low Countries prior to his settling there permanently early the next year. On 4 October he met with his old friend Isaac Beeckman for the first time since early 1619. He sketched for Beeckman some of his discoveries of the previous nine years, including the work on lens theory (compare Section 5). This was prefaced by a statement of the (sine) law of refraction which Beeckman recorded in a short memorandum, illustrated by Figure 12.10, in which for rays aeg and cef, (ab/kg) = (cd/if). There immediately follows Beeckman's description of an analogy through which Descartes sought to explain the law to him:

> [Descartes] considers water to be under st and the rays to be aeg, cef. They seem to undergo the same change as the arms of an equal arm balance, on the ends of which are fixed weights, of which that in water is lighter and raises the arm.[80]

This passage certainly is cryptic; even so patient a Cartesian scholar as Gaston Milhaud was moved to dismiss the analogy as 'bizarre'.[81] But Descartes' conception can be reconstructed, provided one is willing to grant that Beeckman, in an understandable way, garbled or mistook part of the sense of Descartes' exposition.

Let us take Descartes to be suggesting that the behaviour of the incident and refracted rays of light is analogous to the behaviour of an equal arm balance, the arms of which must be bent, or refracted, at the fulcrum

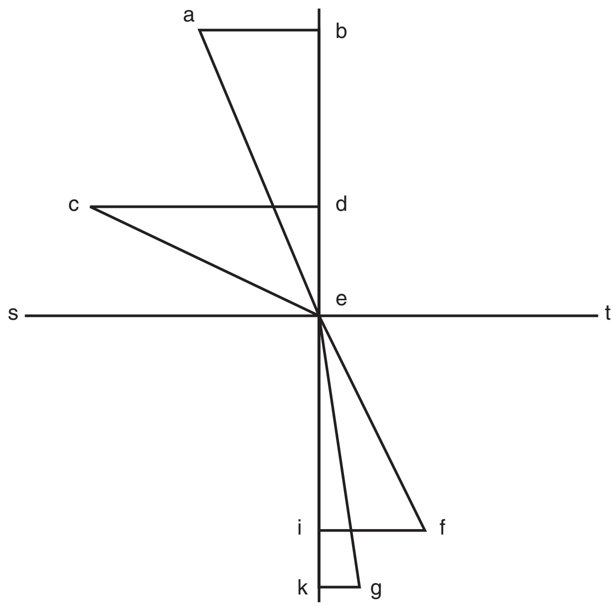


Figure 12.10

to maintain equilibrium under varying conditions of loading. The constant ratio of the force of light in a given pair of media is likened to the constant ratio of the 'effective' weights of identical bodies immersed in a pair of fluids differing in specific gravity. In Figures 12.11 and 12.12 we have a balance whose equal arms can be pivoted about the fulcrum and fixed at the settings required to maintain equilibrium under differing conditions of 'effective' weight. The arms are loaded with two identical bodies of specific gravity SGb. The specific gravity of the upper medium, SGu, and the specific gravity of the lower medium, SGl, are each less than SGb, so the weights 'weigh down' from both ends of the balance. In Figure 12.11, $SGu > SGl$ and in Figure 12.12, $SGu < SGl$. Then, in Figure 12.11, the effective weight of body in the upper medium, $Wt'u$ bears to the effective weight of the body in the lower medium, $Wt'l$, the ratio

$$\frac{Wt'u}{Wt'l} = \frac{SGb - SGu}{SGb - SGl} = \text{const} < 1$$

And in Figure 12.12 the corresponding ratio is:

$$\frac{Wt'u}{Wt'l} = \frac{SGb - SGu}{SGb - SGl} = \text{const} > 1$$

In either case at equilibrium,

$$(Wt'u)\ (r \sin i) = (Wt'l)\ (r' \sin r)$$

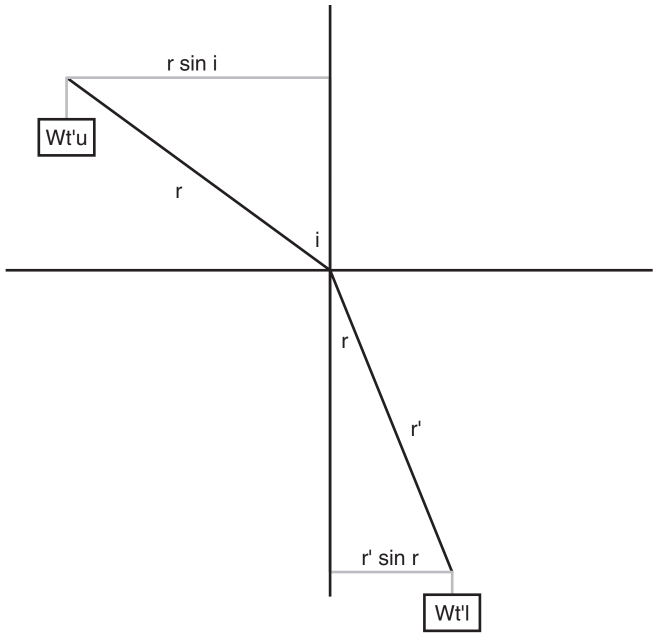


Figure 12.11

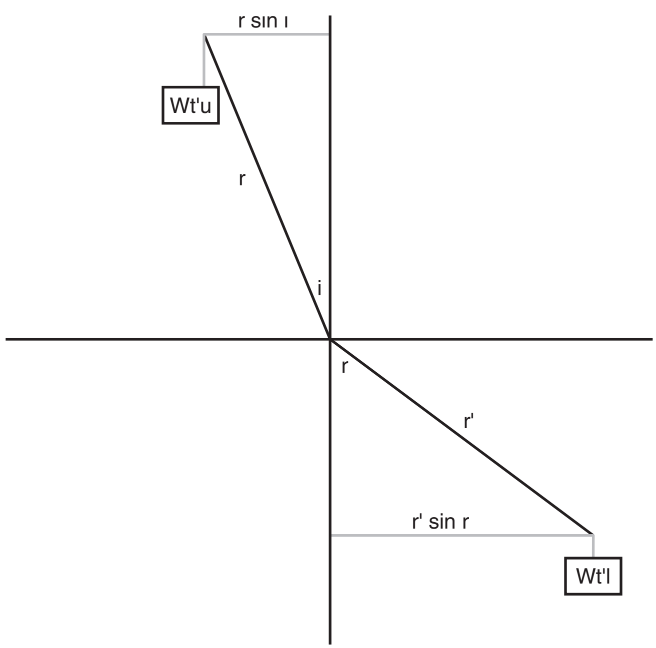


Figure 12.12

where $r \sin i$ and $r' \sin r$ are the effective lever arms, but, $r = r'$, therefore

$$\frac{\sin i}{\sin r} = \frac{Wt'l}{Wt'u} = \text{const}$$

Thus, if equilibrium is to be maintained, in Figure 12.11 the right arm must be dropped towards the normal; in Figure 12.12 it must be removed away from the normal. For a given pair of media, the 'refraction' of the right arm will always be given by the last equation, a veritable 'law of sines' telling us how to adjust the right arm at the fulcrum, for a given setting of the left arm, in order to maintain the condition of equilibrium.

Returning to the entry in Beeckman's *Journal*, we see that his diagram (Figure 12.10) indicates refraction toward the normal in water, but that his discussion specifies that the weight on the right rises due to the buoyancy of the water being greater than that of the air. The inconsistency can be explained by Beeckman having garbled Descartes' explanation. Figure 12.12 illustrates what Descartes intended in the case of a real balance with weights immersed in air and water.[82] But, as we also know from the *Dioptrique*, when Descartes switched from tennis balls to light rays, he had to argue that the force of light is greater in water than in air, in order to explain its refraction toward the normal in water. Accordingly, to apply the balance analogy to the case of light, Descartes must have claimed that the lower medium is rarer than the upper one, so that the effective weight of the body in the lower medium (analogous to the force of the refracted light) is greater than the effective weight of the body in the upper medium (analogous to the force of light in the upper medium), hence that $Wt'l > Wt'u$. This, of course, makes no sense if one still has in mind a real balance with one arm plunged into a real vat of water. To make the balance germane to the behaviour of light passing from air into water, one must abstract from the concrete situation and invoke different media with the appropriate ratio of densities. Beeckman may have become confused in the shift from the concrete case of a balance beam with weights in air and water, to the abstract case where the balance illustrates by analogy the force changes light undergoes in different media. In any case, Beeckman must have garbled the sense of his discussion with Descartes, for he cannot have both his figure and his text.

On this reading, Descartes was offering to Beeckman a particularly fine model for his two recently devised dynamic premisses, as conceived against the background of the theory of light as instantaneous mechanical impulse (as in the later portions of the *Regulae*).

1 The path-independent ratio of the force of light in the two media is modelled by the ratio of 'effective' weights, which depend, of course, on the ratio of the densities of the media.[83] The 'effective' weights, moreover, are beautifully 'path-independent'. The weights hang down perpendicularly from the ends of the arms regardless of the direction

in which the left arm, the 'arm of incidence' if you will, has been set, and regardless of the direction then assumed by the right arm, the 'arm of refraction', in order to maintain equilibrium.

2 The conservation of the parallel component of the force of the light is modelled by the condition of equilibrium, which requires the equality of static moments about the fulcrum.[84]

One should also note that if, as seems likely, Descartes was thinking of his premisses against the background of a theory of light as instantaneous impulse or tendency to motion, then the model is particularly apt for two further reasons. First, weight may be interpreted as a tendency to motion (as Descartes did indeed conceive of it as early as 1619 in the hydrostatics manuscript), and hence as a kind of impulse reiterated from moment to moment; and, second, weight, like a tendency to motion or a light impulse, can be conceived to have a certain gross magnitude (measured by weighing), as well as specifiable components of 'directional magnitude'.[85]

Full circle: Cartesian dynamics, optics and the tennis ball model, 1628–33

Our argument has now travelled almost full circle. It began with an analysis of Descartes' dynamics, which was then used to unpack the tennis ball model and optical proofs in the *Dioptrique*. The reinterpretation of the *Dioptrique* was an important, yet secondary goal; the strategic aim was to take some bearings which could orient our reconstruction of Descartes' route to the sine law and of his struggle to explain it in mechanistic terms. The analysis of the *Dioptrique* uncovered Descartes' two dynamic premisses and the hidden radius form of the law of refraction to which they are best adapted. These findings provided questions and points of reference around which the reconstruction was developed. We can now reverse the process, using the reconstruction of the course of Descartes' optical researches in order to throw new interpretive light on the status of his tennis ball model. We shall discover that far from being central to Descartes' physical optical research, it was really a rather contingent element, explicable by the circumstances and needs which shaped the writing of the text of the *Dioptrique*, and consequently that it does not reflect the trajectory of Descartes' earlier optical researches and is likely to mislead us about them.

Anyone the least familiar with the *Dioptrique* and who has followed the argument thus far will no doubt be wondering why Descartes chose to employ the tennis ball model in the first public exposition of his optics. We have seen that the tennis ball demonstrations of the laws of optics make sense only when supplemented by a knowledge of Descartes' dynamics, which contemporary readers could only have gained from the suppressed *Le Monde*. We were able to recognise cryptic hints of Descartes' dynamics between the lines of the *Dioptrique* only after familiarising ourselves with the relevant portions of *Le Monde*. What is more, we have discovered that kinematic tennis ball type models of light probably played no role in the long gestation of Descartes' physical optics from the 1620 fragment down to the *Regulae* and bent arm balance beam analogy of the late 1620s. If our reconstructions are accepted, they seem to entail that Descartes committed a miscalculation in the *Dioptrique* when he suddenly elected to use a kinematic model for light, and almost completely neglected to provide it with an adequate and explicit dynamic rationale which could link it to his real theory of light as a mechanical impulse.

The canons of historical interpretation suggest that perhaps there is something wrong with our reconstruction if it entails such an unflattering picture of Descartes' capacities. In this section I want to avoid this conclusion by showing why Descartes himself probably believed that the tennis ball model could do an adequate job in the *Dioptrique*, despite certain gross limitations of which he was arguably aware. The answer resides in the demands of Descartes' theory of colour which figures prominently later in the *Dioptrique* and *Météores*. That requires the real spatial translation of balls or corpuscles, so that spin/speed ratios can account for colours; yet, you cannot have a ratio of a tendency to spin to a tendency to move. We are about to see that this problem partially explains Descartes' characteristic reticence about colour theory at the level of the real theory and natural-philosophical systematics. Using tennis balls at least allowed Descartes to finesse the problem in his 1637 texts. The tennis ball model directly linked to the real theory of light, and it could bear the weight of the colour theory. Unfortunately, his colour theory and real theory of light did not cohere. Descartes, I suggest, knew this and struggled with the tensions it generated.

The first step toward grasping Descartes' rationale for the tennis ball model is to understand its wider range of functions in the *Dioptrique* and in the optical portions of the *Météores*. Thus far we have only discussed its use in the demonstration of the optical laws in the second discourse of the *Dioptrique*. In the *Météores* Descartes employed the model in a mechanistic explanation of the causes of the sensations of colours. Descartes was particularly interested in the production of spectral colours when a thin beam of light is refracted through a prism. The explanation of this phenomenon then served as the basis for the explanation of the colours of the rainbow and parhelia. These were among the first problems he addressed in 1629, when he began the work which eventually was embodied in *Le Monde*, the *Dioptrique* and the *Météores*.[86] One must appreciate the importance Descartes would have attached to a general solution to the problem of the (apparent) production of colours through the reflection and refraction of light.

According to Descartes, the tennis balls, whose rectilinear translation models the transmission of light, may also have spin imparted to them when they collide with 'reflecting' or 'refracting' surfaces. In certain situations the spin imparted to the balls is 'nearly equal to their motion in a straight line', and no colours result. But, in other situations, what we may term the ratio of 'spin to speed (of translation)' will be increased or decreased relative to the 'normal' ratio. Such non-normal spin to speed ratios are taken to explain the triggering of sensations of colours, red in the former case, 'blue or violet' in the latter.[87]

Descartes lays the basis for this approach early in the *Dioptrique* in the third of a series of analogies or 'comparisons' through which he proposes to explain and illustrate those properties of light relevant to the understanding of the *Dioptrique* and *Météores*, without having to enter upon the details of his 'philosophy' (element theory, dynamics and real theory of light). The first two analogies explain properties of light travelling through uniform optical media.[88] To explain the phenomena which occur when light encounters a second medium, Descartes introduces the tennis ball model, to which he then adds the spin/speed articulation. He describes how one may impart spin to a tennis ball by grazing or 'cutting' it obliquely with a racket, and he points out how the same thing can happen when a ball bounces obliquely off uneven surfaces. Analogously, colours are produced when rays encounter uneven reflecting surfaces. And, as smooth regular surfaces do not graze the ball, so smooth regular reflecting surfaces do not endow the reflected light with the property of causing the sensation of colours.[89]

Later, in the *Météores*, the explanation of the generation of spectral colours through prismatic refraction, which is fundamental to the explanation of the rainbow and parhelia, proceeds on the basis set down at the beginning of the *Dioptrique*. Dropping all reference to macroscopic tennis balls, Descartes boldly descends to the micro level, to those '*petites boules d'une matiere fort subtile*', whose 'action or movement' constitutes the true nature of light, as, he says, was 'described' in the *Dioptrique*.[90] The *boules*, passing (or tending to pass)[91] through the pores of 'terrestrial bodies', can also acquire spin in certain circumstances. When such *boules* pass obliquely out of the glass prism into the air, their paths are, of course, refracted, and, entering a medium which alters their force of motion, they all acquire a uniform spin in the same direction 'equal to' their rectilinear motion. In this case no colours are produced. But if what we might term the 'beam' of *boules* is narrowed by blocking off with a shade all but a small area of exit on the refracting surface of the prism, then the *boules* in and near one side of the beam will have their spin/speed ratios increased above their normal amount, while those in or near the other side of the beam will have theirs lowered. In the former case the sensation of the colour red will be produced in observers, in the latter case 'blue or violet'. The alteration of the spin/speed ratios necessarily follows from the fact that the *boules* at the edges of the beam must graze *boules* at rest, nestled amid the grosser particles of the shade (and of the air proper). Given their previously acquired uniform speed and sense of spin, the *boules* at one edge have their spin increased and those at the other edge have theirs decreased, and these respective effects also propagate inward from the edges of the beam to some distance, through the contact and interaction among the *boules* making up the beam.[92]

From Descartes' perspective the tennis ball model therefore works rather elegantly within the texts of the *Dioptrique* and *Météores*: in unarticulated form the model facilitates the deduction of the laws of reflection and refraction; then a simple articulation allows Descartes to explain the production of colours in these same processes. (In addition, the articulated model at least held out the promise of a general explanation of colour phenomena, through the study of the reflection and absorption of light by the varied surfaces of coloured bodies.) However, this elegance is achieved in Descartes' texts at some considerable cost, which is chargeable to his views about the real nature of light, and hence to the coherence of the system of natural philosophy he had just created. Descartes, we shall see, was well aware of this cost.

Unfortunately for Descartes, the model for the production of colours works only on condition that the balls, whether tennis balls or *boules* of 'subtle matter', undergo real rectilinear translation, and not merely a 'tendency to motion' or 'action'. 'Grazing' or 'cutting' imparts a real spin, and can do so in the systems of interest to Descartes only as the balls pass by the grazing or cutting surfaces.[93] In such cases there can be no question of merely a 'tendency to rectilinear motion', which might bear some ratio to a spin, or, even worse, to a 'tendency to spin'.[94] There simply is no coherent and convincing analogy in the real theory of light for the spin of the tennis ball or *boules*, or for their mode of acquisition of spin. The articulated tennis ball model therefore cannot be translated into the terms of Descartes' real theory of light as an instantaneously propagated mechanical impulse. In this it differs from the unarticulated tennis ball model used in the proofs of the optical laws. There the model and the real theory collapse into one another, provided one attends to the crucial instant of impact with the reflecting or refracting surface, and concentrates upon the instantaneous, rule-bound alteration of the force and/or determination which occurs at that moment.[95]

Nevertheless, this difficulty need not have worried Descartes all that much insofar as he was concerned with the internal coherence and presentation of *Dioptrique* and *Météores*. Since the full details of his real theory of light and of his dynamics were not on display, because of his decision to abandon publication of *Le Monde* consequent upon the condemnation of Galileo, the tennis ball model could be deployed in these texts without appearing to violate the tenets of his real theory. The very absence of the full details allowed Descartes to write in the *Météores* of the translation of the *boules*, a violation of his real theory of light, but a neat and consistent sequel to the (superficially) kinematical optical proofs.[96]

Earlier, we in effect cast doubt upon Descartes' conceptual and literary skills when we discovered how little of the real dynamical rationale for the optical proofs is present in the *Dioptrique*. Now, however, we can perhaps appreciate that Descartes was cleverly adapting to the fact that *Le Monde* had been suppressed and the *Dioptrique* and *Météores* would therefore appear without any extended discussion of dynamics of the real theory of light. What from one perspective seems to have been an error in Descartes' presentation appears from this new perspective as a quite reasonable strategy of argument, adopted after he had decided that he could not then publish *Le Monde* and the system it contained.

This interpretation obviously assumes that Descartes was aware of the difficulty of identifying the spin/speed model with his real theory of light, and that he made his strategic decisions on that basis. Evidence on this score can be gleaned from both of Descartes' treatises of systematic natural philosophy, *Le Monde* and *Principia philosophiae*, as well as from the *Météores* itself. In sum, Descartes never discussed the spin/speed explanation in detail in his systematic treatises: in *Le Monde* Descartes refuses to mention colour as an essential phenomenon of light and so relieves himself of the onus of having to explain colour in a manner inconsistent with the rest of his discussion.[97] His behaviour, I contend, was quite intentional. Later, in *Principia philosophiae* he still avoided explicit discussion of the spin/speed explanation. With one exception, all questions about the causes of colour were dealt with by referring the reader to the *Dioptrique* and *Météores*.[98]

But to say that Descartes was aware of this problem is not to suggest that it always haunted him with equal vigour. The intensity of the problem would have varied from context to context and from time to time. When, in 1644, Descartes finally published a system of mechanical natural philosophy, the problem would have loomed large and caused his evasions. But earlier, in the mid-1630s, when he was committed to suppressing *Le Monde* and only publishing the *Discours de la méthode* and its three *Essais*, he could well have been satisfied with the heuristic and organisational role played by the tennis ball model within the combined texts of the *Dioptrique* and the *Météores*.[99]

Conclusion

In conclusion, we briefly note two further developments related to the reconstruction offered thus far. Taken in conjunction with the reconstruction, they open a rather wide perspective on the interrelation of Descartes' agendas in corpuscular mechanism, geometrical optics, physico-mathematics and methodology between 1618 and 1637. The first issue deals with Descartes' attempt in 1626–8 to weave a methodological tale of discovery around his experience in optics over the previous several years. Properly deciphered, Descartes' tale bears witness to some of the complexities, quandaries and pitfalls of his optical work, as revealed by our reconstruction. The second issue relates to Descartes' exploitation of his dynamic rationalisation of the law of refraction in his attempt to frame general laws of nature in his first systematic natural-philosophical treatise, *Le Monde*.

Descartes mythologises his experience as an optician: method and optics in Regulae 8

In Rule 8 of the *Regulae* Descartes describes, in a carefully chosen subjunctive mood, how the law of refraction, the anaclastic curve, and the physical explanation of refraction might all have been discovered by using his method. This part of the Rule dates from 1626–8: it obviously post-dates the discovery of the law of refraction, the first elaboration of lens theory and the initial attempts to provide a physical rationalisation of the law.[100]

Descartes' story in Rule 8 of the methodological investigation of the anaclastic and other problems unsurprisingly contains an initial analysis and a concluding, demonstrative synthesis, and follows the general lines of the method doctrine extractable from the early *Regulae*.[101] The analysis consists in the discovery of that ordered series of questions upon the solution of which the resolution of the anaclastic problem ultimately depends. If, Descartes begins, one were going to search for the anaclastic curve using the method, the first step would be to see that the solution depends upon first discovering the law of refraction, 'the relation which the angles of refraction bear to the angles of incidence'. At this point, Descartes observes, a mathematician would have to give up the search, for all he can do is assume some relation and work out the consequences. Further analysis shows that the problem of the law of refraction in turn depends upon knowledge of 'physics' as well; for the relation between the angles of refraction and incidence depends in some way upon the manner in which light passes through media. But the answer to that question would be seen to depend on the more general issue of 'what is the action of light', and the answer to that question would be seen to depend in turn upon the answer to the ultimate question in this series, 'what is a natural power?' One would have to determine, by a 'mental intuition', what this 'absolute nature' is. This would be the last step in the analysis and the first in the deductive synthesis. Unfortunately, Descartes does not inform us as to the content of this 'intuition'; but we can presume that light and all other natural 'powers' are to be explained mechanically, by corpuscular motion, impact or tendency to motion. In any case, having discovered this by 'intuition' one would have to pursue the rest of the synthesis by proceeding back along the chain of questions, deducing the more relative natures from the less relative ones. However, our deduction might stall at some point, for example at the step of trying to deduce the nature of light from the nature of natural powers in general. In such cases one would have to proceed by 'analogy'. The investigator must 'enumerate all the other natural powers, in order that the knowledge of some other of them may help him, at least by analogy . . . to understand this one'. Again, we are not told anything more here about the analogies, but we are acquainted with one of Descartes' favourites from this period, the bent arm balance he was soon to expound to Beeckman.[102] Allowing for such occasional and unpredictable recourse to analogy, the synthesis would ultimately lead from a theory of natural powers, via a theory of light to a deduction (and explanation) of the law of refraction, and thence to a theory of lenses.

As one would expect, Descartes' methodological tale about how he 'could have done optics' bears no relation to the complex trails of research reconstructed in this paper. Elsewhere I have argued what when such tales of particular researches are woven out of the discursive cloth of a grand doctrine of method (Descartes' or anyone else's) some characteristic effects follow. On the one hand, the 'thick', *sui generis* conceptual and procedural density of the field of inquiry in question is necessarily suppressed and lost from view. This entails that the method story really cannot accurately describe any actual or even possible course of genuine practice in that field; it necessarily structurally mystifies the dynamics of knowledge production and evaluation in that field. On the other hand, the little methodological story bears structural similarities to other such stories which can be generated within the same method discourse. To the methodologist, therefore, the story seems to be true, or at least possibly true, and his belief in the unity and efficacy of his method are enhanced by this further 'evidence' of its value.[103]

Given all this, Descartes' story is to be construed as a rationalisation of the complex and sometimes abortive course of his researches; as an attempt to show that since the results could in principle have been produced by using method, they should enjoy certain epistemological and methodological accolades. After all, our reconstruction indicates that Descartes' lived experience of 'being an optician and physico-mathematician' had not been entirely happy or tidy. On the one hand, there was the tortuous and none too orderly course of his researches, which had at long last produced some results of note. On the other hand, despite or indeed because of these results, he confronted a confusing array of resources, theories, programmes and commitments, the disorderly residues of eight or nine years of endeavour. Among these we can number: (a) a law of refraction discovered using the possibly discredited image locating principle; (b) an unarticulated theory of light as mechanical impulse; (c) two dynamic premisses read out of (a) in the light of (b); (d) a body of lens theory in the process of refinement and alteration; and, (e) at least one analogy for the deduction of (a) from (c). Upon this chaos of personal history and conceptual baggage the method tale imposes a double order.

There is the diachronic order of an ideal course and flow of research, and conflated with, or contained within, that diachronic order is a logical/explanatory order, revealing the deductive relations holding amongst his theories and principles.[104]

This interpretation further allows us to make sense of two otherwise peculiar aspects of Descartes' tale: his appeal to the use of analogies, and his reticence about the nature of light and natural powers in general. On the first question, it would appear likely that Descartes introduced an analogy when moving to the step of deducing the nature of light because he simply did not quite know what else to say about the issue. At the time he possessed an unarticulated theory of light as mechanical impulse, two rough-hewn premisses read from the Mydorge diagram, and the balance analogy. The theory of light was not closely articulated to a system of mechanistic natural philosophy; he simply did not have one. Similarly, the dynamic premisses were not yet part of a system of dynamics, forming part of that larger system of natural philosophy. Leaving aside the Mydorge diagram, read 'physico-mathematically', the only thing holding together the theory of light and the premisses was the balance analogy: it modelled light as an impulse and it modelled the two premisses; and, it could be used to explain/deduce the law of refraction. In Rule 8 Descartes is probably simply echoing this as yet unsystematised and unresolved state of affairs.[105]

A similar sort of explanation applies to the question of why Descartes is coy and reticent about the 'nature of natural powers' in general and about the 'nature of light' in particular. We may surmise that Descartes preferred to be non-committal, because he had not yet committed himself to articulated theories on either topic. The beauty of the method tale is that it can accommodate this vagueness and hide it by enfolding it in 'orderliness'. Certainly he had a theory of light, a mechanistic outlook on nature and premisses from which to deduce the law; but none of this was settled or elaborated. Since he had to hand a workable analogy for deducing the law and modelling light, it was better in such circumstances to inject into the tale a sub-discourse on the use of analogy, than it was to imply that any of his currently unsettled ideas might have the status of products of 'intellectual intuition' or 'deduction' therefrom.

The optical exemplar for Descartes' laws of dynamics?

As we have seen, Descartes' mature dynamics distinguishes between the absolute quantity of a force of motion, and its directional manifestations, expressed in Laws 1 and 3 in *Le Monde*. We may now suggest that these principles derived from a further generalisation of his original reading of the Mydorge diagram. Descartes first read the diagram for some basic principles of physical optics, assumptions about the quantity and directional quantity of the force of light. But what about the laws of nature which he had to construct after 1629, when he began to write *Le Monde*? How better to base the laws of nature than to use as an exemplar the dynamic principles revealed by successful optical research; Light, after all, is just an impulse, so its behaviour clearly reveals the basic dynamics of forces and determinations. Descartes would have had every reason to be confident that his optical exemplar was well chosen and correctly analysed, and so he would have had every reason to think that his dynamics of force and determination could be premissed upon his having cracked the code of the physics of refraction.

If the reconstruction offered in this paper carries some degree of plausibility, it brings into relief complex diachronic and conceptual relations amongst Descartes' early enterprises and demonstrates the centrality of geometrical optics, and optical concerns in general, in the evolution and cross-fertilisation of his agendas in physico-mathematics and corpuscular-mechanism. It also suggests, consistently with Sepper's contentions elsewhere in this volume, something about the manner in which Descartes practiced physico-mathematics and 'figured out' solutions to its problems. There was more to the young Descartes' projects than has yet been clarified in the literature, despite the fact that it was from these complex and intertwined endeavours that there emerged his first seminal texts, the *Regulae*, *Le Monde*, the *Discours* and the *Essais*.

Notes

1 Research for this paper was supported in part by the Australian Research Council; the Humanities Research Centre, Australian National University; and the University of Wollongong Research Committee.

2 *Oeuvres de Fermat*, ed. C. Henry and P. Tannery, 4 vols (Paris, 1891–1912), ii. 108–9, 117–24, 485–9; Paul Mouy, *Le développement de la physique Cartésienne* (Paris, 1934), 55; Gaston Milhaud, *Descartes savant* (Paris, 1921), 110.

3 It has long been well established that it is quite unlikely Descartes stole the law from Snel, as some contemporaries maintained. See P. Kramer, 'Descartes und das Brechungsgesetz des Lichtes', *Abhandlungen zur Geschichte der Mathematischer (Natur) Wissenschaften* vol. 4 (1882), 235–78; and D.-J. Korteweg, 'Descartes et les manuscrits de Snellius d'après quelques documents nouveau', *Révue de Métaphysique et de Morale* vol. 4 (1896), 489–501.

4 The understanding of determination used here develops work of A.I. Sabra, *Theories of Light from Descartes to Newton* (London, 1967) 118–21; A. Gabbey, 'Force and inertia in the seventeenth century: Descartes and Newton', in S. Gaukroger, ed., *Descartes: Philosophy, Mathematics and Physics* (Sussex, 1980), 230–320; M. Mahoney, *The Mathematical Career of Pierre de Fermat 1601–1665* (Princeton, 1973); S. Gaukroger, *Descartes: An Intellectual Biography* (Chicago 1995); O. Knudsen and K.M. Pedersen, 'The link between "Determination" and conservation of motion in Descartes' Dynamics', *Centaurus* vol. 13 (1968), 183–6; T.L. Prendergast, 'Motion, Action and Tendency in Descartes' Physics', *Journal of the History of Philosophy* vol. 13 (1975), 453–62; and Peter McLaughlin in this volume.

5 These rudiments appear in the so-called hydrostatic manuscript of 1619. See J.A. Schuster, '*Descartes and the Scientific Revolution 1618–34: An Interpretation*'

unpublished PhD dissertation, Princeton University, 1977, 93–111; Gaukroger op. cit. (1995) 84–9. It should also be noted that *Le Monde* itself contains a reference to the text of the *Dioptrique* attributing the distinction between force of motion and directional force of motion to that earlier text. AT x. 9. cf F. Alquie (ed.) *Descartes Oeuvres philosophiques,* i. 321 n. 2.

6 AT xi. 38.

7 AT xi. 43–4: S. Gaukroger, ed. and trans., *Descartes: The World and Other Writings* (Cambridge, 1998): 'I shall add as a third rule that, when a body is moving, even if its motion most often takes place along a curved line and, as we said above, it can never make any movement that is not in some way circular, nevertheless each of its parts individually tends always to continue moving along a straight line. And so the action of these parts, that is the inclination they have to move, is different from their motion. [. . . *leur action, c'est à dire l'inclination qu'elles ont à se mouvoir, est different de leur mouvement*]' [29]. And, 'This rule rests on the same foundation as the other two, and depends solely on God's conserving everything by a continuous action, and consequently on His conserving it not as it may have been some time earlier, but precisely as it is at the very instant He conserves it. So, of all motions, only motion in a straight line is entirely simple and has a nature which may be grasped wholly in an instant. For in order to conceive of such motion it is enough to think that a body is in the process of moving in a certain direction [*en action pour se mouvoir ver un certain coté*].' [29–30].

8 In the passages cited above Descartes in his discussion of the third law defines '*action*' as '*l'inclination à se mouvoir*'. He then says that God conserves the body at each instant '*en action pour se mouvoir ver un certain coté*'. This would seem to mean that at each instant God conserves both a unique direction of motion and a quantity of 'action' or force of motion. In other words the first law certifies God's instantaneous conservation of the absolute quantity of tendency to motion, the 'force of motion'. The third law specifies that as a matter of fact in conserving 'force of motion' or '*action*', God always does this in an associated unique direction. The first law asserts what today one would call the scalar aspect of motion, the third law its necessarily conjoined vector manifestation. Just because he recognizes that some rectilinear direction is in fact always annexed to a quantity of force of motion at each instant, Descartes often slips into abbreviating 'directional force of motion' by the terms 'action', 'tendency to motion' or 'inclination to motion', all now seen in context as synonyms for 'determination'.

9 *Le Monde*, AT xi. 45–6, 85.

10 *Le Monde*, AT xi. 85. Descartes argues from the first and third laws of nature that at the instant of time the body is at point A, it tends in and of itself along the tangent AC. The circular tendency along AB is that part of the tangential tendency which is actively opposed by the physical constraint of the sling and hence gives rise to the centrifugal tendency to motion along AE. For the sake of whiggish edification it can be noted that had Descartes dealt with the centrifugal constraint on the ball offered by the sling, instead of the circular tendency (which violates the first law in any case), he might have moved closer to Newton's subsequent analysis of circular motion.

11 *Le Monde*, AT xi. 85.

12 AT vi. 94.

13 On this interpretation of 'determination' in the *Dioptrique* see Sabra, op. cit. 118–21.

14 AT vi. 95–6.

15 AT vi. 95.

16 AT vi. 96.

17 Cf. Sabra, op. cit., 85, 110; Mahoney, op.cit., 379–80; and Richard Westfall, *Force in Newton's Physics* (New York, 1971), 65–6, were among the first scholars to appreciate this point. Previous students of Descartes' optics, such as Mach, Ronchi, Scott and Boyer, did not, as cited by Sabra, op. cit., 110.

18 This crucial point was first noted by Mahoney, op. cit., 378–9 in the course of his path-breaking reinterpretation of Descartes' optical proofs in terms of relations amongst quantities and directional quantities of forces.

19 AT vi. 97.

20 AT vi. 97–8.

21 AT vi. 97.

22 AT vi. 97–8. Descartes later supplies arguments concerning the mechanical structure of optical media to explain why light bends toward the normal when passing into a denser medium. AT vi. 103.

23 Mahoney, op. cit., 379, was the first to suggest how the tennis ball model could be referred back to an imputed Cartesian dynamics in order to explicate Descartes' proof.

24 It is noteworthy that Descartes himself thought about his tennis ball model proof in precisely the manner we have just used to render it in terms of his dynamics and apply it to light rays. He later wrote to Mydorge for Fermat to explain the manipulation of the speeds (forces of motion) and determinations in the tennis ball proof: 'The [principal] determination is forced to change in various ways, in accordance with the requirement that it accommodate itself to the speed [force of motion]. And the force of my demonstration consists in the fact that I infer what the [principal refracted] determination must be, on the basis that it cannot be otherwise than I explain in order to correspond to the speed, or rather the force which comes into play at B.' Here Descartes views his proof in dynamic terms, as a deduction of the new refracted principal determination induced at the instant of impact with the surface, rather than in kinematic terms, as a deduction of the position of the tennis ball at a certain time after impact with the surface. To Mydorge for Fermat, 1 March 1638, AT ii. 20.

25 This derivation merely reworks Sabra's well known analysis of Descartes' demonstration. (Sabra op. cit., 97–100, 105–6, 116.) The only difference is that here we deal with quantities of *forces* and their directional components (determinations), rather than with quantities of *speed* and their directional components, as Sabra did. The reason is that we have insisted upon the centrality of the former concepts for Descartes and we have argued that Descartes could reduce phenomenal speeds to instantaneously exerted quantities of force of motion, so that speeds and tendencies to motion could be treated under the same conceptual and geometrical framework. We shall return to Sabra's analysis below.

26 We take it that in the spirit of Bachelard's epistemological and historiographical conception of *récurrence*, such analytical whiggism is not at all a thing to be avoided. Cf. S. Gaukroger, 'Bachelard and the Problem of Epistemological Analysis', *Studies in History and Philosophy of Science* vol. 7 (1976), 189–244, at 229–34.

27 AT vi. 98.

28 AT vi. 98–9.

29 To Mersenne for Bourdin, 3 December 1640, AT iii. 250.

30 Descartes is tacitly appealing on the empirical level to an indubitable fact: when dealing with a pair of homogenous media, refraction is an interface phenomenon. His dynamical premisses are consistent with this fact, but they cannot be consistently articulated so as to allow the deduction of this fact, and this fact only.

31 AT vi. 99–100.
32 Ibid.
33 J. Lohne, 'Zur Geschichte des Brechungsgesetzes', *Sudhoffs Archiv* vol. 47 (1963), 152–72; J. Lohne, 'Thomas Harriot (1560–1621) The Tycho Brahe of Optics', *Centaurus* vol. 6 (1959), 113–21; J.A. Vollgraff, 'Pierre de la Ramée (1515–1572) et Willebrord Snel van Royen (1580–1626)', *Janus* vol. 18 (1913), 595–625; J.A. Vollgraff, 'Snellius' Notes on the Reflection and Refraction of Rays', *Osiris* vol. 1 (1936), 718–25; C. de Waard, 'Le manuscrit perdu de Snellius sur la refraction', *Janus* vol. 39/40 (1935–6), 51–73.
34 Mersenne, *Correspondance*, ed. C. deWaard et al, 17 vols. (Paris 1932–88). i. 404–15.
35 Ibid, 404.
36 Ibid, 405.
37 Ibid, 406.
38 AT x. 336ff; also Beeckman *Journal*, ed. C. deWaard, 4 vols. (The Hague, 1939–53), fol. 333v ff.
39 Descartes repeatedly mentioned that during this period he recruited Mydorge and the master artisan Ferrier in an attempt to confirm the law and construct a plano-hyperbolic lens. For example, Descartes to Golius, 2 February 1632, AT i. 239; Descartes to C. Huygens, December 1635, AT i. 335–6.
40 In addition to the material cited in previous note, see Descartes to Ferrier, 8 October 1629, AT i. 32; 13 November 1629, AT i. 53ff; Ferrier to Descartes, 26 October 1629, AT i. 38ff. In the mid 1620s Mydorge annotated Leurechon's *Récréations mathématiques*, a popular work dealing with mathematical tricks and fancies of a natural magical character. Leurechon's work was first published anonymously in 1624 and reprinted several times thereafter with additional notes, including those by Mydorge. I have consulted (Jacques Ozanam) *Les Récréations Mathématiques . . . Premierement revu par D. Henrion depuis par M. Mydorge* (Rouen, 1669). Mydorge notes concerning the nature of refraction '*Ce noble sujet de refractions dont la nature n'est point esté cogneue n'y aux anciens, n'y aux modernes Philosophes et Mathematiciens iusque à present, doit maintenant l'honneur de sa découverte à un brave Gentilhomme de nos amis, autant admirable en scavoir et subilité d'esprit.*' (157).
41 DeWaard admits that the copy he examined dated from 1631 at the earliest, Mersenne, *Corr.* i. 404.
42 W. Shea, *The Magic of Motion and Numbers: The Scientific Career of René Descartes* (Canton, MA.,1991), 243 n.38.
43 Mersenne, *Corr.* i. 411–13.
44 Mersenne, *Corr.* i. 408–11. Schuster, op. cit. (1977), 321–7 documents the textual and mathematical claims made in this paragraph.
45 Mersenne, *Corr.* i. 408–9.
46 Cf. Fig. 12.3 above.
47 AT x. 341–2; Beeckman, *Journal*, fol. 338r.
48 Ibid.
49 Schuster, op.cit. (1977), 326–7 documents the textual and mathematical claims made in this paragraph.
50 This principle appears in Alhazen, Pecham, Witello, Roger Bacon and Maurolico; cf. Robert Smith, *A Compleat System of Optics* (Cambridge, 1738) para 212, cited in C. Turbayne, 'Grosseteste and an Ancient Optical Principle', *Isis* vol. 50 (1959), 467–72, at 467.
51 Lohne, op. cit. 1959, 116–17; Lohne, op. cit. 1963, 160. Gerd Buchdahl provides a particularly clear statement of the methodological role played by the image principle in Harriot's discovery of the law in his 'Methodological Aspects of Kepler's Theory of Refraction', *Studies in History and Philosophy of*

Science vol. 3 (1972), 265–98 at 284. Willebrord Snel's initial construction of the law of refraction also followed the type of path indicated by the Lohne analysis. See Vollgraff, op. cit. (1913) (1936); deWaard, op. cit. (1935/6) and Schuster, op. cit. (1977), 313–15.

52 J. Bossa, 'Annexe note', *Archives Neerlandaises des Sciences Exactes et Naturelles*, ser II vol. 13 (1908) xii-xiv. Cf. Schuster, op. cit. (1977), 311.

53 Sabra, op. cit., pp. 97–100, 105–6,116.

54 See note 25 above.

55 AT x. 242–3.

56 Sabra, 106, 111.

57 Schuster, op. cit. (1977), 93–111, Gaukroger, op. cit. (1995), 84–9. J.A. Schuster, 'Descartes' *Mathesis Universalis* 1619–1628', in S. Gaukroger, ed., *Descartes: Philosophy, Mathematics and Physics* (Sussex, 1980), 41–96, at 48–9.

58 D.Lindberg, 'The Cause of Refraction in Medieval Optics', *British Journal for the History of Science*, vol. 4 (1968), 23–38; on Snel's adherence to this type of conceptualisation, see Vollgraff, op. cit. (1913), 622–3.

59 Kepler held that light is an immaterial emanation propagated spherically in an instant from each point of a luminous object. Refraction, he maintained, is a surface phenomenon, occurring at the interface between media. The movement of the expanding surface of light is affected by the surface of the refracting medium, because, according to Kepler, like affects like, hence surface can only affect surface, and the surface of the refracting medium 'partakes' in the density of the medium. He analysed the effect of the refracting surface upon the incident light by decomposing its motion into components normal and parallel to the surface. The surface of a denser medium weakens the parallel component of the motion of the incident light, bending the light toward the normal; a rarer refracting medium facilitates or gives way more easily to the parallel component of the motion of the incident light, deflecting it away from the normal. (The normal component of the motion of light is also affected at the surface by the density of the refracting medium, weakening or facilitating its passage, but not contributing to the change of direction.) *Ad Vitellionem Paralipomena,* Ch.1 Prop. 12, 13, 14, 20, in J. Kepler, *Gesammelte Werke*, ed. M Caspar (Munich, 1938ff), ii. 21–3, 26–7. I have termed this Kepler's official theory of refraction, because it is not his only articulated discussion of the causes of refraction (and their geometrical representation) offered in *Ad Vitellionem*, as we are now about to see.

60 *Ad Vitellionem Paralipomena,* in *Gesammelte Werke*, ii. 81–5.

61 Kepler, loc. cit., 86.

62 Schuster, op. cit. (1977), 336–9. Cf. also the problem solving techniques attributed to the young Descartes by Sepper in this volume, 'Figuring things out'.

63 For example, Kepler's official theory of refraction (note 59 above) dealt with the parallel and normal components of the motion of the light, asserting that both are weakened at the interface, whilst attributing the refraction to the alteration in the parallel component alone. In the traditional optical literature it was, of course, also thoroughly commonplace to attend to the comportment of the normal and parallel components of the motion of light when discussing its refraction and reflection.

64 Again, our interpretation should be compared to Sepper's thesis in this volume about how the young Descartes solved problems via strategies of figural representation ('Figuring things out'). Here Descartes uses the routine representation of the components of rays to represent and articulate Kepler's interesting physical hypothesis.

65 AT x. 242–3.

66 Kepler, *Ad Vitellionem*, *Gesammelte Werke* ii.107.
67 Loc. cit., 89–90.
68 Issues about Descartes' ontology of light in the fragment – whether Aristotelian, Keplerian or mechanistic – are addressed below as part of the explication of the development of his mechanistic rational of the law of refraction in the 1620s.
69 Had Descartes assumed that the parallel component varies either directly or inversely with the density, he would have again deduced 'tangent laws' with slightly differing indices of refraction. There seems no way to proceed directly from the assumptions of 1620 to the sine law of refraction, unless one is prepared to introduce Newtonian complications about the variation in components as functions of the angle of incidence, a way of conceiving the problem foreign to Descartes in 1620, 1626, as well as 1637.
70 The discerning reader will note a difficulty in this reconstruction. It has been argued that Descartes and Mydorge (as well as Snel) used the traditional image finding rule in their path of research leading to the law of refraction. But, unlike Harriot, the three later discoverers presumably were well aware of Kepler's new theory of vision which cast grave doubt on the use of the traditional rule. Descartes, after all, was working on a mechanistic version of Kepler's theory of vision around the same time he and Mydorge discovered the law and his 1620 optical fragment indicates familiarity with Kepler's new work on vision. This fascinating issue cannot be addressed in full here. Suffice it to say that the problem is more Descartes' than our own. That is, there is evidence that Descartes suppressed discussion of his actual path of discovery for several reasons, one of which was the embarrassing point that his work depended upon an optical principle he could no longer accept. For example, his odd methodological story about how the law might be discovered, offered in rule 8 of the *Regulae ad directionem ingenii*, seems intended to occlude this fact, and to mythologise several of his other theoretical quandaries, under a cloak of persuasive, but necessarily vacuous 'method talk'. The matter is briefly touched upon in J.A. Schuster, 'Whatever Should We Do With Cartesian Method: Reclaiming Descartes for the History of Science' in S. Voss (ed.), *Essays on the Philosophy and Science of René Descartes* (Oxford, 1992), 195–223, and below. I am working on a study of Descartes' methodological tales of optics in the *Regulae* and *Dioptrique*, and how other reconstructions of his discovery path compare to that offered in the present paper, e.g. Kramer, op. cit.; Milhaud, op. cit. 108ff; Milhaud, 'Descartes et la loi des sinus', *Revue general des Sciences* vol. 18 (1907), 223–8; Sabra, op. cit.; and Mark Smith, 'Descartes's Theory of Light and Refraction: A Discourse on Method', *Transactions of the American Philosophical Society* vol. 77 pt 3 (1987), 1–92.
71 One can also imagine slightly lesser degrees of articulation, involving, for example, merely a corpuscular-mechanical explanation of optical sources and media and lacking cosmological articulation, and possibly lacking a highly articulated theory of dynamics.
72 Cf. note 5 above.
73 E.g. Beeckman, *Journal* iii. 27–8.
74 For Descartes' similar reaction to Beeckman's celestial mechanical speculations see Schuster, op. cit. (1977), 567–79.
75 On the larger functions and uses of the tennis ball model and Descartes' difficulties with it, see below.
76 Schuster, op. cit. (1980).
77 I have also shown that the structure of Descartes' method discourse necessarily prevented it being able to achieve what it proclaims itself able to achieve, whilst, at the same time, that structure necessarily produced, for Descartes

and other believers, a connected set of illusions, literary effects about the method's unity, applicability and efficacy. Cf above note 70, and below, as well as J.A. Schuster, 'Cartesian Method as Mythic Speech: A Diachronic and Structural Analysis', in J.A. Schuster and R.R. Yeo, eds., *The Politics and Rhetoric of Scientific Method: Historical Studies* (Dordrecht, 1986), 33–95 and Schuster, op. cit. (1992).

78 Schuster, op. cit. (1980), 59–64. Descartes writes in Rule 12 that the external senses 'perceive in virtue of passivity alone, just in the way that wax receives an impression [figuram] from a seal.' He intends no mere analogy: just as the wax is physically impressed with the image of the seal, 'the exterior figure of the sentient body is really modified by the object'. All of our sensations, whether of light, colour, odour, savour, sound or touch, are ultimately caused by the mechanical disturbance of the external sense organs. From the sense organs the impressed 'figures' are transmitted to the common sense via the nerves. This occurs 'instantaneously' by the passing of a pattern of mechanical disturbance. 'No real entity travels from one organ to the other', just as the motions of the tip of a pen are instantaneously communicated to its other end, for 'who could suppose that the parts of the human body have less interconnection than those of the pen'. Patterns are so registered in the common sense can then be imprinted in the imagination, there to be stored in memory from the future 'attention' of the vis cognoscens, or to be immediately attended to in sense perception. AT x. 412–4.

79 Schuster, op. cit. (1980), pp. 61–2. Although Descartes focuses upon the mechanical causation of sensation and perception, it is clear that a mechanical theory of light underpins the entire discussion. Whatever the essential nature of external objects may be, Descartes implies, they act upon the perceiving subject in a mechanical manner. In the case of visual perception, therefore, light (or the optical media through which it acts) mechanically impresses the 'figures'. Presumably light is an instantaneously transmitted mechanical impulse: Descartes' mention of instantaneous mechanical nervous action, and his analogy of it to the instantaneous transmission of motion from one end of a pen to the other, suggest that light is considered to act in the same fashion. Note also that although the pen analogy is applied to nervous action, it is similar to the analogy of the blind man's staff, used later in the *Dioptrique* to illustrate the instantaneous mechanical transmission of light.

80 AT x 336; Beeckman, *Journal*, fol. 333v.

81 Milhaud, op. cit., 110.

82 It would also illustrate the case of a 'tennis' or cannon ball whose motion is refracted away from the normal in water, as discussed later in the *Dioptrique* (AT vi. 97–8). Beeckman and Descartes might perhaps have discussed this phenomenon in 1628.

83 The only problem with Descartes' analogy of course is that greater force [effective weight] depends upon placement in a rarer medium and vice versa, thus implying a disanalogy between specific gravity and refractive 'density' of an optical medium.

84 This again is a figural modelling of the conditions of the problem, in the manner suggested by Sepper's analysis in this volume, 'Figuring things out'.

85 As Stevin, the stimulus for the hydrostatic manuscript, had taught with his near approach to the parallelogram of forces, mainly applied to the non-vertical components of weight. S. Stevin, *The Principle Works*, Vol. 1, ed. E.J. Dijksterhuis (Amsterdam 1955), 183–5.

86 To Mersenne, 8 October 1629, AT i. 23.

87 *Météores*, AT vi. 331–2.

88 First, he uses the analogy of the blind man's staff to illustrate the instantaneous propagation of light without the passage of any material (or immaterial) entity. The analogy clearly derives from the pen analogy used earlier in the *Regulae*. As the blind man receives from the far end of his staff only instantaneously conveyed tendencies or resistances to motion, so light rays are only lines of tendency to motion propagated instantaneously through the contiguous particles of optical media (AT vi. 84–6). The second analogy deals with the rectilinear propagation of light rays, their propagation in infinitely many directions from a luminous point, and their ability to cross without impeding each other. Descartes' model is a vat filled with half crushed grapes and new wine. The analogy is carried out by manipulating putative lines of tendency-to-descend running from wine particles on the surface of the vat to hypothetically voided points on its bottom, a procedure clearly borrowed from the hydrostatics manuscript of 1619 (AT vi. 86–8).

89 Although he will later deal with the production of colours through refraction of light, Descartes introduces the 'spin/speed' articulation of the tennis ball model in the case of reflection (AT vi. 90–1), because it is much more easily grasped in common sense terms, and because, of course, he has not yet even shown how the simple tennis ball model can be applied to the law of reflection and then extended to the law of refraction.

90 *Météores*, AT vi. 331.

91 Loc. cit., 332.

92 Loc. cit., 331–4.

93 At times Descartes speaks of a part of the speed of translation of a ball being converted into spin (e.g. AT vi. 90). He was no doubt thinking of everyday macroscopic analogies, such as a tennis ball appearing to lose some its incident speed upon acquiring a spin after bouncing obliquely on the ground.

94 Descartes uses this infelicitous locution at AT vi. 333.

95 For, as we have established above, at the moment of impact, the tennis ball (reduced to a weightless, frictionless point) behaves exactly the way a light impulse would – indeed dynamically speaking the two are identical – and the superficially kinematic aspects of the model 'momentarily' drop from view.

96 Looking more deeply into this, one realises that at the level of the published texts the coherence of Descartes' presentation really turned on the dual character of the proofs of the optical laws: on the one hand, the tennis ball optical proofs were based on his dynamics and drew their cogency from the way they modelled instantaneous alterations of force and/or determination. Of course, their true character was only partly inscribed in the text, and for the most part had to be sought between the lines. The dynamic underpinnings were hinted at, and could be mobilised if questions arose, as occurred in the subsequent debates concerning the proofs, for example in the remarks cited above at note 24. On the other hand, the optical proofs were presented in an overtly, if superficially, kinematic fashion. As such, they motivated and paved the way for the spin/speed articulation which would explain colours.

97 When presenting his real theory of light in chapter fourteen of *Le Monde*, he listed twelve properties of light and explained them as arising from tendencies to motion transmitted through the spherical *boules* of his 'second element'. Colour is not mentioned explicitly as one of these properties; but, it is implicitly contained in the last two properties, described in terms of capacity of the 'force' of a light ray to be increased or decreased 'by the diverse dispositions or qualities of the matter that receives them'. Descartes' 'explanation' of these properties makes no mention of colour and seems intended more to elaborate the explanation of the tenth property, refraction. As for refraction and reflection themselves, Descartes passes up the opportun-

ity of introducing the tennis ball model (or moving *boules*), and simply refers the reader to the *Dioptrique* (AT x. 97–103).

98 The exception occurs in an obscure corner of the final part of the French version of the treatise [*Princ.* IV. art. 131, AT ixB. 274], where Descartes explains the properties of coloured glass. Leaving aside this limited and late passage, which is Descartes' and/or Picot's afterthought, we see that Descartes steadfastly refused to introduce the spin/speed model into his systematic work. And the likely reason for this is that the model cannot be made to agree with his real theory of light as a tendency to motion. Further evidence of Descartes' awareness of the problem and its intractability may be found in the *Météores*. In the passages discussed above (note 94), Descartes twice writes of the *boules*' 'tendency' to move and 'tendency' to spin. Evidently he was caught between the content and the grammar of his real theory on the one hand, and the mechanical rationale of his spin/speed model on the other. At this point of tension his discourse falters and wavers, despite the fact that here in the published text of 1637 he could (for the foreseeable future) have got away with the consistent pretence that light consists in the translation of *boules*.

99 The little we know about the course of composition of the *Dioptrique* tends to confirm this picture of a Descartes reluctantly satisfied, for the time being, with the tennis ball model in the publications of 1637. The *Dioptrique* is first mentioned in a letter to Mersenne of 25 November 1630 (AT i. 179), over a year after the problems of parhelia and the rainbow had first stimulated his work on a system of corpuscular-mechanical natural philosophy. Descartes writes that he wishes to insert into the *Dioptrique* an explanation of 'the nature of light and colours', a task which has held him up for six months. This will virtually turn the *Dioptrique* into a 'system of physics', an 'abridgment of *Le Monde*', and so acquit him of his promise to Mersenne, made in April 1630, to finish the system within three years. He adds that if the reception of the *Dioptrique* shows he can persuade people of the truth, then he will proceed to complete his treatise on metaphysics begun earlier in 1629. Two main difficulties seem to have been haunting Descartes. First, the explanation of the nature of colour had proven a most difficult proposition. One suspects this was not only due to the intricacies of his articulated tennis ball model, but also because of the dawning realisation that it bore no convincing analogy in the real theory of the 'nature of light'. Second, Descartes was clearly still undecided about how much material from his emerging system of corpuscular-mechanism should or could appear in the *Dioptrique*. In the letter he toys with the idea of *adding* a section on the true nature of light and colour, and thus implying that he already possessed some version of the model-based presentation he later published. Again, part of his hesitation and indecision may have related to the difficulty of linking the spin/speed articulation to his real theory of light. In January 1632 he sent to Golius what he termed 'the first portion of the *Dioptrique*', dealing with 'refractions without touching upon the rest of philosophy' (AT i. 235). This, too, tends to indicate that Descartes still contemplated publishing in the *Dioptrique* more of his dynamics and real theory of light than we find in the publication of 1637. If so, he was probably then still facing the problem of the relevance of the spin/speed articulation to the real theory. In the end Descartes' problems were solved on a pragmatic basis, motivated by external events. When he learned of the condemnation of Galileo and decided to withhold *Le Monde* from publication, he reorganised his publication programme, producing within three years the *Discours* and three *Essais* in the form with which we are now familiar. The reorganisation allowed him to design the *Dioptrique* and the optical portions allotted to the *Météores* around the tennis ball model, without having to face up to the problem of whether

the model in its articulated form could represent aspects of the real theory of light. In this respect, perhaps, he came to see the demise of *Le Monde* as something less than a complete disaster, since it allowed him to resolve the problem of presenting and justifying his optical achievements. Again, from this perspective, he may well have viewed the tennis ball model as a qualified success.

100 It can also be shown that it is the first of the passages added to the *Regulae* in Paris and leads directly to the core of the third stratum of the text. Cf. above note 76 and Schuster, op. cit. (1980), 58–9.

101 AT x. 393–5.

102 Perhaps he also had in mind other analogies for the action and refraction of light, for example, a rudimentary and unarticulated kinematic model, a tennis ball model; we simply do not know.

103 Schuster, op. cit. (1986, 1992).

104 Like a myth viewed in a Lévi-Straussian perspective, the method discourse provides a structure which imposes order on this jumble of biographical and in part contradictory conceptual meaning-tokens, by means of a narrative of particular events and actions which is at bottom yet another instance of his core myth of method. C. Lévi-Strauss, *Structural Anthropology* (Norwich 1972), 216, 224. Alternatively, if one prefers Roland Barthes' view of myth, we might say Descartes' account amounts to a none too convincing rational reconstruction, motivated by a host of personal, philosophical and ideological concerns, and posing as a true story of the discovery. R. Barthes, 'Myth Today' in *Mythologies* (St. Albans,1973), 109–59.

105 His only alternative would have been to begin discoursing about the Mydorge diagram, physico-mathematics, how to read Kepler, as well as admitting to having used the now superseded traditional image location rule etc., a most unmethodical undertaking, if our reconstructions are to be believed.

13 A ‘science for *honnêtes hommes*’

La Recherche de la Vérité and the deconstruction of experimental knowledge.[1]

Alberto Guillermo Ranea

Scholars have tended to view Descartes’ science in the light of his most conspicuous metaphysical ideas. Though recognizing some kind of distinction between natural science and metaphysics, they very often evaluated the former using criteria stemming from the Cartesian *cogito*, clear and distinct ideas, or the mind-body problem. Within this rationalist framework it became customary to accept uncritically the neglect of experiment and the radical reduction of physics to geometry as defining features of Cartesian science. Accordingly, Descartes’ alleged disregard of experiments would have been just a scientific version of his metaphysical and epistemological arguments against the trustworthiness of sense experience as presented, for instance, in the First Meditation. As a result, the boundaries between natural science and metaphysics became blurred, and those aspects of Descartes’ scientific thought considered by commentators as unsuited to his metaphysical or epistemological ideas were simply disregarded.

This received interpretation of Cartesian thought is not altogether false. On the contrary, the central, and exclusive, place of Descartes’ metaphysical and epistemological ideas in the reception of his thought supports it strongly. Three and a half centuries of scholarship cannot simply be considered as just a huge historical mistake. What I shall be challenging is its allegedly universal validity as an interpretation of all aspects of Descartes’ writings. Two important facts concerning observation and experiment remained unexplained by it. First, during the second half of the seventeenth century Cartesianism was, either directly or indirectly, associated with some sort of experimental stance and even with meetings – usually informal – for witnessing and performing experiments. Second, Descartes’ writings and letters include an immense number of references to observations and experiences, either performed by himself or by other, mostly unknown people. In the received view of Cartesian science and philosophy these passages have been at best adapted to the mandatory Cartesian metaphysics of the *cogito* and its ideas or, more often, they have simply been ignored. I will offer here a reassessment of the role played by experimental and observational evidence in the constitution of Cartesian science. I will try to show that experiment and observation, far from being a puzzling relic of incidental practices, do actually belong to the very core of Cartesianism in science and philosophy. More precisely, I would like to suggest that the role of Descartes' metaphysics and epistemology was to clear observation and experience from the customary accusation of unreliability.

Descartes' project would not, therefore, have aimed at the substitution of a priori, non-observational premisses for observational ones as the foundation of science. The aim of Cartesian natural philosophy would have been to offer authoritative regulations for the acceptance and rejection of experimental evidence. Descartes' natural philosophy would be, then, an early essay at finding a solution to the problems caused by the reporting and replication of experimental facts and observations. Accordingly, the important though intricate nuances in meaning that words such as 'experience', 'experiment', and 'observation' display in Descartes' texts are irrelevant to our present account. What most concerned Descartes was to determine under which circumstances a report of an observation should be credited as an accurate and objective description of what has been actually experienced. Thus it is immaterial whether we are faced with ordinary experience or with sophisticated experiments: both unskilled observers and trained experimenters have equally to report in a convincing way their observations either of natural phenomena or of experimental findings. The reports are akin to perceptual judgments and, as such, could be false.[2]

I will try to show that Descartes, in his attempt to regulate the acceptance of experimental and observational reports, has clearly anticipated Robert Boyle and Thomas Hobbes in raising the issue of experimental knowledge in the Scientific Revolution. As we will see in short, Descartes discusses in his writings and letters most of the same issues that, according to a widespread view on experimentalism in the seventeenth century, would have been an exclusive feature of the British provenance of the debate on experimental matters.[3] According to my interpretation, however, the origin of the debate should be antedated up to at least 1629, and also relocated in the French background where Descartes developed his natural philosophy in close relationship with Mersenne's circle.

The decisive influence of the issue of experimentalism upon current debates on social deconstructivism in scientific knowledge[4] challenges us to review its basic tenets in the light of what we discover about Cartesian natural philosophy, for what will emerge is an image of the 'experimental life' in the Scientific Revolution that could seriously impugn both the accuracy of the historical account of its birth in the Baconian settings of the Royal Society of London, and the social deconstructivist conclusions drawn from it. Concerning the former, I will try in what follows to offer documentary evidence for my conjecture, showing that Descartes discussed in depth with his correspondents the very same issues that, according to the received view on experimentalism, would have been raised originally in mid-seventeenth century London. On the latter question, my aim is to show that Descartes' solution to the problem of experimentalism offers good arguments for a rationally grounded alternative to the more relativistic conclusions of social deconstructionism.

The claim that Descartes played a central role in the history of experimentalism is challenged by at least three very well documented and established lines of argument among Cartesian scholars. First of all, Descartes' natural philosophy lies chronologically and geographically outside the site of the debate on experiment. According to Steven Shapin, the foundation of the Royal Society of London and Boyle's activities in it should be considered as the foundation stone of experimental life. Accordingly, Descartes' intellectual attitude towards experiment would actually belong to the prehistory of the problem. Second, the predominance of theoretical issues throughout Descartes' writings, his disrespect for experimental results and his proverbial mistrust of observation, certainly conspire against my hypothesis. In a word, the a priori adoption of a rationalist stance would have lead Descartes to devalue experimental evidence. Third, according to Shapin and Schaffer, the debate on experimentalism proves that every solution to the problem of knowledge is also a solution to the problem of social order. However, political and social issues are, if not completely absent, at least very well hidden in Descartes' writings. Thus, it would be misleading to take his natural philosophy as the starting point of the controversy on experimentalism.

These objections strongly suggest the need of some deconstructivist stratagem in order to unearth Descartes' implicit assumptions on experiment and observation. I will try to show however, that we do not have to resort to any 'stranger's account' in order to raise the issue of experimentalism in Descartes. In fact, he straightforwardly introduces his natural philosophy partly as a solution to the same troubles with experimental evidence that, according to Shapin and Schaffer, eroded the objectivity of Boyle's experimental procedures. The deconstructivists' strategies are thus redundant in this case, and their relativistic conclusions immaterial. To this end we will invert the traditional image of Cartesian rationality. Instead of an abstract theoretical force ruling Descartes' work in an a priori way, Cartesian rationality in natural philosophy would be the denouement of the troubles raised by the new experimental spirit in the social and political life of Europe during the first decades of the seventeenth century. More precisely, I would like to suggest that Descartes would have intended his natural philosophy to provide a criterion for closing controversies generated by the unreliability of the reports of what had been allegedly observed by other *savants* under different experimental circumstances.

La recherche de la vérité par la lumière naturelle, an often neglected minor work of Descartes, will assist us by providing an invaluable access to his philosophy in the making.[5] It is not my present purpose to arbitrate on the dispute about the date and circumstances of its composition. Nor will I try to argue against the authoritative scholars who have shown convincingly that it adds nothing new to Descartes' basic metaphysical and epistemological doctrines.[6] But *La recherche* does contains some details of relevance to our present problem. It reveals to whom and with what aim Descartes devoted his efforts in natural philosophy. The *honnête homme* of the dialogue, Poliandre, is more than just a character in a pedagogical divertimento of Descartes' mature years.[7] He represents all the moral and intellectual qualities required to be the depository of Descartes' confidence. He has not been trained in the Schools; he is a *gentilhomme* courtier and soldier, a man of action.[8] He is called in the dialogue a 'neutral person', because he has not been trained in any learned trend in philosophy or in theology.[9] This makes of him the ideal partner for talking about 'all the things in the world, considering them as they are in themselves'.[10] He is the very embodiment of the *bons sens*, of this faculty of judging truth and falsity not yet corrupted by any factious commitment to a school. From his description in the dialogue it is difficult to decide whether Descartes depicted by him Queen Christina of Sweden, Princess Elizabeth, or Constantijn Huygens. I do not think, however, that the dialogue was dedicated to any particular person. In scope, *La recherche* is more akin to the *Discours de la méthode* than to the *Principia*, and like the former, although written as if it were directed to someone in particular, it actually seems to address a wider range of people: the *honnêtes gens*.

It is outside the scope and aim of this chapter to determine whether they do belong to a particular social stratum of their time. However, everything hints at a sort of *gentilhomme*, a member of the gentility. In a recent book,[11] Stephen Shapin has suggested that the early seventeenth-century gentleman's word was deemed to be trustworthy by definition. Heavily relying on Montaigne's *Essaies*, his account contains valuable information on the features of the gentlemanly culture that could shed light on *La recherche*. According to his account, the condition of being a gentleman meant that each member of this class should be 'deemed to be perceptually competent'.[12] The veracity of their accounts was grounded on their simplicity, while 'liars revealed themselves by the diversity of their accounts'.[13] Moreover, a gentleman should avoid reporting on extraordinary, incredible facts since they can only lead to controversy. His conversation should aim at agreement, not at argument.[14] Unfortunately, Shapin again isolates English science, as if it were quite different from the Continental science embodied in the Cartesian formal methodological search for certainty.[15] In so doing, he misses the opportunity of viewing the problem within a wider framework, since he considers only the final product of Descartes' reflexions on the problem of certainty and truthworthiness, his rationalism. *La recherche* may help us to see that both the British and the Cartesian positions stemmed from the same problem, that raised by the incorporation of gentlemanly behaviour into the scenario of experimental science. Where then does the difference between both lie?

La recherche offers a unique answer to this question. Descartes does not believe that the mere circumstance of being a gentleman would be enough for grounding the entire edifice of knowledge on it. A gentleman never consciously lies, but he might lie involuntarily. His honesty would not then be enough in order to secure knowledge. His word may be betrayed by his credulity, as in the case of those 'melancholics who take themselves to be a vase, or who take some part of their body to be enormous, swearing that what they see and touch is just as they imagine it to be'.[16] In this context Descartes introduces his doubts concerning the reliability of observation under the guise of an argument on dreaming and waking states. He does it with a very suggestive apology that clearly confirms the present account:

> It is true that an *honnête homme* would be offended if you told him that his beliefs cannot have any more rational basis than theirs [=the melancholics] since he relies, like them, on what the senses and the imagination represent to him. But you cannot take it amiss if I ask whether you are, like other men, liable to fall asleep.[17]

The *honnête homme* is, then, the gentleman; we cannot doubt his word without being offensive.

It is also interesting to notice that in the dialogue systematic doubt does not extend as far as mathematical knowledge. The deceiving God, a device contrived in the *Meditationes* in order to subject mathematical reasoning to the overall rule of the hyperbolic doubt, is limited here to questioning observational evidence, using the argument from the possibility that we might be dreaming. While in the *Meditationes* Descartes says that it is possible that God 'can mislead me whenever I add 2 and 3 together, or whenever I count the sides of a square',[18] in *La recherche*, after asking Poliandre 'how can you be certain that your life is not a continuous dream?'[19] Eudoxe offers the following version of the deceiving God in support of his cautious doubts about the involuntary unreliability of Poliandre's perceptions.

> In particular, how can you be certain of this when you have learned that you were created by a superior being who, being all-powerful, would have found it no more difficult to create us just as I am describing, than to create us as you think you are.[20]

I think that we have here Descartes' earliest and most radical motivation for trying to provide a new legitimation of scientific knowledge on different premisses. Cartesian rationalism in natural philosophy would then be the denouement of a process that started from his initial reservations about the reliability of other people's reports to the only reliable source of certainty accepted by early seventeenth-century European society outside the authority of the Schools, namely a gentleman's word on his perceptual experiences. To extend doubt to the realm of mathematical reasoning would have been unnecessary, seeing that ignorance of mathematics was so proudly confessed by the *honnêtes gens*.

Poliandre, the *honnête homme* of the dialogue, accepts Eudoxe's argument but with the proviso that it does not belong to the culture of the *gentilhomme*:

> For myself, however, I fear I should go woolgathering if I tried to consider such abstract matters, for I am a man who has never engaged in study or accustomed himself to turning his mind so far away from things that are perceivable by the senses.[21]

Universal doubt, such as that expressed in the dreaming argument, blurs the boundaries between the world of commonsensical gentlemen and the fantastic dreamworlds of the *curiosi*. It is interesting to notice that Epistémon, the supposed representative of Scholasticism according to a received view of the dialogue, is actually interested in *curiosa*.[22] As Eudoxe put it, the insatiable curiosity that infects Poliandre is unsuitable for 'orderly souls'.[23] But what was wrong with this apparently innocuous 'desire for knowledge'? It creates an illusion as inappropriate to *honnêtes hommes* as the chimerical products of fancy – the folly of desiring a completely detailed knowledge of the furniture of the reality.[24] This marks a first difference between what depends exclusively on perceptual experience (either real things or fantastic rarities), on one side, and reason, on the other. The former offers no criterion to *honnêtes hommes* by which to distinguish between what is chimerical and what is real and, as such, useful to life.[25] But even if the *honnêtes hommes* were naturally wise enough to reject the charlatan's fancies, every singular fact of the real world will appear to him as important as any other. Thus 'an *honnête homme* is not required to know Greek or Latin any more than the languages of Switzerland or Brittany, or the history of the Empire any more than that of the smallest state in Europe'.[26] The world of 'those simple forms of knowledge which can be acquired without any process of reasoning'[27] would be like the indiscriminate assortment of all kinds of things at a flea market, where only the customer's personal taste and interests create an informal hierarchy of more or less appealing objects.

This is precisely what Descartes is seeking to avoid in *La recherche*, when addressing his thoughts to the *honnêtes hommes*. He is trying to free them from the unending quarrels about subjectively grounded views of the world. Descartes' intentions are, however, far from being the fruits of a philanthropic spirit. *La recherche* clearly shows that Descartes' aim is to educate the *honnêtes hommes*, because he needs them in order to free his science from controversial matters. In other words, Descartes assigns to *honnêtes gens* the role of judges of scientific controversies, but with the purpose of counting on them for the success of his doctrines. He indoctrinates them with his views, but in such a subtle and careful way that the addressees of his teaching never realize that they are being indoctrinated by him. Unfortunately, the fragmentary character of the dialogue does not allow us to guess what Epistémon's final reaction would have been, but what remains of it does strongly suggest that he accepts, without protestation, Poliandre's role as a judge of his controversial conversation with Eudoxe. This conjecture is by no means weakened by the fact that, right after Eudoxe confers on Poliandre the responsibility of deciding between him and Epistémon, the latter expresses his fears that Poliandre might be acting with a sectarian spirit.[28] On the contrary, Epistémon's suspicion is quickly dismissed by Eudoxe as inappropriate to the present conversation: 'We can leave that to someone who wants to be a professor or to debate in the Schools',[29] a role that none of the three characters of the dialogue is intended to play anyway.

But how can a man so utterly simple as Poliandre become the judge of the controversy between Eudoxe and Epistémon, if his naive attitude to the reliability of his perceptual experience – his only trained intellectual tool – has been so convincingly put under suspicion by the universal doubt? How did Descartes manage to transform Poliandre's honest and humble initial stance[30] into the self-confident judge of the last part of the remaining fragment of *La recherche*? As many scholars have pointed out, the answers to these questions add nothing new to the content of the Cartesian doctrine. However, I would like to call attention to the juncture at which this transformation takes place in the dialogue. Poliandre is endowed with the skills of a judge just after he has been able to answer in Cartesian terms the question: 'But what are you – you who have doubts about everything but cannot doubt that you yourself exist?'[31] While he still answers 'so I shall say I am a man',[32] Poliandre is not reliable as a judge, since this statement only makes sense within the framework of the teaching of the Schools, here embodied in the tree of Porphyry.[33] But when Poliandre replaces his first answer with 'I am absolutely convinced that I exist, so convinced that it is totally impossible for me to doubt it',[34] then and only then is he appointed by Eudoxe, with the tacit agreement of Epistémon,[35] the judge of their dispute.[36] At this moment, the humble *honnête homme* became a pioneer example of a new kind of teacher, and his words grew in confidence to such an extent that he was led to assert: 'I am pleased to see that on this occasion at any rate you must acknowledge me as your teacher and regard yourselves as my pupils.'[37]

It is truly regrettable that the dialogue, left unfinished by Descartes, has come down to us also in such a fragmentary condition. We can only assume that in what followed Descartes would not have rejected any of the conclusions reached in the first part of it. The extant version stopped when Eudoxe and Epistémon get ready to listen to what looks like a lecture from Poliandre, at the their suggestion. Let us first remember that Poliandre reaches this position after having been taught by Eudoxe to mistrust his sense experiences and the honest, though maybe unreliable, word of a gentleman. He then allows Eudoxe to lead his thoughts as if they were the pure and exclusive product of his mind. At the end of the surviving fragment, Eudoxe encourages Poliandre:

> With this in view, I say we should let Polyander speak on his own. The only master he follows is common sense, and his reason has not been marred by any false preconceptions. So it is hardly likely that he will be deceived; if he were, he would soon realize it, and would have no trouble getting back onto the road.[38]

These words of Eudoxe are centrally relevant to our present purpose. Had they been written by a social deconstructivist of our time, it would have certainly caused a scandal among the defenders of the pure rationality. They sum up clearly the objective of the dialogue's pedagogical plot. Eudoxe needs the alliance with Poliandre as the judge of the controversy in order to convince the recalcitrant Epistémon. To this purpose, however, Poliandre's 'natural light' and his sense experiences are no more reliable than those of his curious adversary or of a charlatan. Eudoxe then trains up Poliandre's 'common sense' in Cartesian terms, so that, when the latter has to judge cases of scientific controversies, he will unconsciously speak the Cartesian language as if it were the mother tongue of human reason – a sort of mesmeric induction or innocuous brainwashing.

We can therefore conclude that *La recherche de la verité* displays Descartes' thought in the making. It describes a process whereby the purest intellectual aspirations are inextricably intermingled with his most deeply personal traits and his ambition of controlling and persuading his peers in social rank, the *gentilhommes*. The dialogue turned out thus to be an efficacious succedaneum for deconstructivist strategies such as 'playing the awkward' or 'the stranger's account'. It teaches us how to become aware of the intrigues that lay behind Descartes' most intimate autobiographical pages. Many authoritative scholars have interpreted the dialogue alternatively in the light of the *Meditationes* or the *Principia*, or of his relationship with Princess Elizabeth or Christina, Queen of Sweden. Notwithstanding, *La recherche* also evinces significant affinities with the 'history of his mind', the *Discours de la méthode*. I would like to stress the suggestive presence in the *Discours* of one of the most important metaphors of *La recherche*, the trope of living in the desert, in the wilderness. It appears in the Introduction to the latter[39] as well as at the end of the Third Part of the former.[40] It is not exclusive to these two writings of Descartes, however: it is also present throughout his correspondence between 1629 and 1649. Descartes' retreat from society may quite possibly have been caused by a sort of disordered psychological condition, or induced perhaps by the *gentilhomme* culture,[41] or by a combination of both. What is more important to my present exposition is the fact that, whatever the cause, the solitude of the desert is, according to Descartes, the ideal site for his thought. In *La recherche*, for instance, he views himself 'as would a king if his country were so isolated and cut off from others that he imagined there was nothing beyond his frontiers but infertile deserts and uninhabitable mountains.'[42] In the same vein, the Third Part of the *Discours* ends with a comparison of his stance in the Netherlands to the solitary and retired life 'as if in the most remote desert',[43] an image almost literally repeated in the correspondence with Guez de Balzac and Mersenne, and, under a more abstract guise, with Princess Elizabeth and Chanut.[44] Stephen Gaukroger gives us a valuable hint when he asserts that Descartes, like Balzac, 'would write at a distance, in an important sense, following his move to the Netherlands'.[45] He is by no means a reclusive hermit, nor is he indifferent to worldly affairs. Nevertheless, he constantly tries to shield his isolated position from intruders of any sort, ranging from the inoffensive Ferrier up to the most distinguished doctors of the Sorbonne. Like the ruler of the kingdom amidst the desert, Descartes has to act at a distance if he wishes to influence the wider society with his philosophy, and like the king of *La recherche*, he will teach the still uncontaminated *honnêtes gens* how to be free from the despotic, sectarian authority of the learned. His followers, the converted *honnêtes hommes*, should also transform their peculiar positions into other Cartesian kingdoms in the solitude of the desert. Treacherous charlatans, erudite doctors, pompous pedants and know-it-alls – in a word, the *curieux* represented in *La recherche* by Epistémon before his conversion into Cartesian rationality – will be hopelessly excluded from these kingdoms. The Biblical resonances of the trope are suggestive: like the earthly paradise, the Cartesian kingdom is located amidst the desert. And like the inhabitants of the mythical paradise, the citizens of the Cartesian kingdom have not eaten from the forbidden tree. The *curiosi*, on the contrary, are doomed to be at the mercy of an insatiable hunger for knowledge that makes them unsuitable for living in Eden. Or, in the words of *La recherche*, 'just as I think that each land has enough fruits and rivers to satisfy the hunger and thirst of all its inhabitants, so too I think that enough truth can be known in each subject to satisfy amply the curiosity of orderly souls'.[46]

La recherche, therefore, displays Descartes' intentions when addressing the *honnêtes hommes*. The dialogue starts with a combination of philosophical, scientific, and social factors, and it ends in a purely theoretical discourse on Cartesian premisses by the just-converted Poliandre. If we now follow Descartes' correspondence, we will find a similar process, whereby not only the objective of, but also the content of, his natural philosophy flow from his desire to spread his influence over the learned community and to control its activities at a distance. When read in the light of our account of 'Cartesian rationalism in the making', the correspondence shows us an aspect of Descartes' philosophy closely related to the issue of experimentalism in the continental Europe of his time. This element should not surprise us as altogether novel, since it belongs to the very core of Cartesian philosophy: the distrust in perceptual cognition. However, a hidden dimension of it becomes manifest as soon as we put it within the framework of what we have already found in *La recherche*. In many letters, the reliability of the senses is not questioned in terms of our individual experience, but in terms of other people's reports on what they have allegedly observed. This shift in the question of perceptual cognition appears also in several of his major works. In the *Discours de la méthode*, for instance, Descartes warns us about the risk of naively trusting in experiments performed by others in our absence.[47] Modern interpreters have tended to neglect this version of the argument as if it had no bearing on the correct interpretation of Descartes' thought. However, we discover in it one of those features of experimental life that, according to Steven Shapin, owes its origin exclusively to the pioneering debate between Robert Boyle and Thomas Hobbes. But as a matter of fact, Descartes was faced with similar troubles each time his correspondents gave him an account of what they had seen or heard. As in the later British debate, the role of witnessing in providing the foundation of knowledge was at stake in many of Descartes' letters. I will try now to show that the issue over the reliability of witnessing proves to be a major motive in the development of Descartes' philosophy. If the success of the Cartesian kingdom depends on the support of a neutral lay gentry, its members should be already indoctrinated in Cartesian premisses in order to appraise correctly the observational reports of devious charlatans and *curieux* – the inhabitants of those lands beyond the deserts that have no common boundaries with the Cartesian kingdom. This would have led Descartes to write a natural philosophy for *honnêtes gens*, or

> the proposal for a Universal Science which is capable of raising our nature to the highest degree of perfection, together with the Dioptrics, the Meteorology, and the Geometry, in which the author, so as to give proof of his universal Science, explains the most abstruse topics he could choose, and does so in such a way that even persons who have never studied can understand them.[48]

One of the objectives of such general science was to provide the *honnêtes hommes* with a criterion for determining at a distance whether something reported by other people actually happened or not. More precisely, Descartes tries to teach them to see the world exclusively in Cartesian terms. The correspondence suggests that Descartes aimed at the establishment of an informal society of *honnêtes hommes* for the control of scientists and experimenters. Although his avowed scope is to actually free them from any dependence on strangers' accounting or witnessing, the price they have to pay for this freedom is high: they will become dependent on Descartes' word on what is there and what is not there in the world. The metaphor of the 'kingdom amidst the wasteland' in *La recherche* summed up this conflation of the epistemological and the social in the roots of Descartes' thought. It appears also in his letters at the very moment when Descartes decides to make a fresh start in his philosophy. The trope of the earthly paradise is suggestively connected, in a letter to Mersenne of 20 November 1629, with the chimerical dream of a new language based upon a *bonne science* 'enabling peasants to be better judges of the truth of things than philosophers are now'.[49] Though dismissed as unfeasible, the project displays Descartes' early confidence in common people because they are still uncontaminated by the venom of the forbidden knowledge of the Schools. In spite of the decline, in his time, of the belief in the earthly paradise, everything hints here at the utopia of its restoration. Just as in the paradise of the religious tradition, natural inborn knowledge – here equated with Cartesian science – will be instrumental in recreating the peaceful prelapsarian conditions on the earth. Besides, when trained in the principles of Cartesian science, the *honnêtes gens* will successfully overcome the restless dissatisfaction of the *curieux* that, like the punishments in hell, are deemed to last forever. And although the Biblical import of the metaphor vanishes in the rest of the letters, the literary image of an oasis surrounded by a protective desert appears all through them. The desert is not a determined geographical site; neither is it the pious solitude of the monastic life, nor the bucolic life at the Hermitage chosen by Guez de Balzac. It is the febrile tempo of Amsterdam's business life, in which the philosopher lives amidst an indifferent crowd entirely devoted to practical affairs.[50]

However, the Cartesian kingdom in the desert will present its weakest flank when Descartes hears through Mersenne that parhelia or 'mocking' suns had been observed at Rome on 20 March 1629. On 8 October 1629 Descartes wrote to Mersenne that he will abandon a former project in order to 'make a systematic study of the whole of meteorology'.[51] As Stephen Gaukroger rightly observed, this is a decisive turning point in Descartes' intellectual career: 'The new project that Descartes is to start upon is *Le Monde* . . . The one he abandons is, I suggest, the *Regulae*.'[52] This fresh start coincides with his search for protection in his retreat to the Netherlands, i.e. to the desert,[53] and his decision to write a general physics[54]: 'and rather than explaining just one phenomenon, I have decided to explain all the phenomena of nature, that is to say, the whole of physics.'[55] This drastic change in the direction of his research is disproportionate to its avowed motive, a rather dubious meteorological phenomenon. What led Descartes to this decision is, I think, a problem closely related to his retreat from the learned society. Descartes became fully aware that in the case of the parhelia he is relying on what other *savants* allegedly have observed in the sky. His protected isolation amidst the desert is thus threatened by the likely invasion of charlatans and doctors. The question was, then, how to be definitively independent from the authority of such testimonies, but without missing what they had of profit for his science. His first, unqualified, answer was to plainly reject all the experiences made by other people but not yet by himself. This answer proved, however, to be too restrictive. So, he proposed a mitigated version of it. He accepts only the accounts of those phenomena that, although out of the reach of his own private observation, are nevertheless explainable within the principles of his natural philosophy. The rest of them were simply dismissed as utterly inexistent, fantastic facts. From 1629 on Descartes assumes therefore the role of an unappealable judge of the reality of phenomena. His correspondence with Mersenne proves how central this issue was to their scientific exchange. From Descartes' letters we know that the Minim friar has constantly kept him informed about what has been observed either in nature or in the laboratory. It is apparent that Descartes' reaction to this avalanche of information does not follow a consistent pattern. He often rejects as impossible what Mersenne reports, but on many occasions he naively accepts the reality of incredible facts. It is very difficult to explain coherently, with the help of just one hypothesis, all these circumstances. However, we can point out a few, though important, patterns in his assessment of Mersenne's reports. In many cases he rejects the information just because it comes from unreliable reporters. The moral and the epistemological dimensions of Descartes' thought reappear in these texts. Monsieur Petit,[56] the 'Geostaticien',[57] and the Italians in general,[58] are on a priori grounds and without further explanation rejected as unreliable witnesses, because of their leaning to lying and deceiving. Even Mersenne is sometimes suspected because of his naive credulity. Nevertheless, these cases are not representatives of the true Cartesian solution to the problem. As he wrote to Mesland on 2 May 1644,

> The moral error that arises when we believe something false with good reason, for example because someone of authority has told us, involves no privation provided it is affirmed only as a rule for practical action, in a case where there is no moral possibility of knowing better. Accordingly, it is not strictly an error. But it would be one if it were asserted as a truth of physics, because the testimony of an authority is not sufficient in such a case.[59]

The moral integrity of an observer cannot therefore guarantee the reality of what he has experienced. The veracity of the *honnête gens* is not enough for setting on the basis of knowledge. 'Witnessing science', a central piece in Shapin's account of how experimental life in the early Royal Society was closely related to British legal procedures, is explicitly rejected by Descartes as a guarantee of the priority of discoveries in science. For this reason he mocks Beeckman for the journal he kept of his personal scientific achievements. What would happen if someone raises suspicions about the truthfulness of the diary? In this case, comments Descartes ironically, it would be necessary to resort to witnesses of what Beeckman has recorded in his journal, or to call a notary in order to draw up a document that legally certifies it.[60] In his answer to Beeckman, Descartes acts wholly in accordance with his desire, expressed in *La recherche*, of becoming the distant king of the scientific community. As a matter of fact, although no public notarial document or witness is truthful enough to attest the veracity of Descartes' discoveries in science, he is convinced that they will recognize in them the fruits that stem from the bottom of his *ingenium*.[61] The misleadingly personal and subjective overtones of this statement quickly disappear when we interpret it in the light of the project of *La recherche*. As we have seen, nothing guarantees the truthfulness of what other people have allegedly observed, because they are either unreliable charlatans or *honnêtes gens* unwillingly victims of their naïveté. The correspondence shows us many strange phenomena such as red rains,[62] silk growing in a maiden's forehead and rose thorns blossoming in the body of a Spaniard,[63] objects fired to the zenith that never return to the Earth,[64] birth-marks and small effigies of dogs in the urine of people suffering from rabies,[65] experiments carried out on falling bodies in Italy, and parhelia. Descartes comments on the existence and possibility of all these 'facts' as if he were passing sentence on them. He acts as the judge of the controversies these observations might raise in the distant scientific community. The new project he announced on occasion of the appearance of the parhelia in the Italian sky is intended to be the constitutional law in support of the objectivity of the judge's sentences. From then on, if the alleged fact may be explained or deduced from the principles of his natural philosophy, we shall take it as a real fact and the report of its observation as reliable. Through the *Météores* first, and then in his natural philosophy, Descartes seeks to set objective rules for settling controversies. As he writes to Mersenne on 13 November 1629, 'I think I have found a way of unfolding all my thoughts which will satisfy some and with which others will have no cause to disagree'.[66] The same sentiment is expressed when he considers his philosophy as being beyond any dispute: 'There are already so many views in philosophy that are merely plausible and can be maintained in debate that if my views are no more certain and cannot be approved of without controversy, I have no desire ever to publish them.'[67] Descartes will debate willingly with all those who agree in accepting his principles as the intellectual framework of the discussion. But those who reject them, such as Roberval,[68] do not deserve polite treatment. The end of the controversies would therefore be a *Pax Cartesiana*.

Descartes' natural philosophy would, therefore, have been his answer to the problem as to whether others' accounts of their observations are or are not reliable. He does not admit either the phantasies and exaggerations of charlatans nor the testimonies of gentlemen as criteria for settling experimental issues. Their shared Achilles' heel lies in the fact that, as he wrote to Mersenne on 9 January 1639, 'everyone looks at things with a bias which is peculiar to him'.[69] Descartes then tries to replace his own description of what is there in the world for all the multiple and variegated personal, private views of the rest of the mortals. A homogeneous world results from his success. Heterogeneity, singularity, rarity will then be confined to the shameful lands of charlatans, unworthy of the favour of the *honnêtes gens*. Even the observations of highly respected persons, such as of Pierre Gassendi[70] or Constantijn Huygens are submitted to the tribunal of Cartesian law. A whole programme for experimental life is thus set up. In a clear and explicit Baconian vein, the 'particular observations, on someone's word' are dismissed from the experimental schedule.[71] As Descartes puts it in *La recherche*, only the observations 'drawn from ordinary facts about which everyone has heard' will allow *honnêtes gens* to discover, by themselves, the rest of the truths.[72] Within the context we have studied above of the goals of *La recherche*, this means that a 'mediocre mind' not trained in the Schools[73] will be able to assess scientific knowledge if it follows exclusively the leadership of the Eudoxe-Descartes assessment of what has to count as a fact.[74]

I would finally like to hint at a project that might be considered as an accomplishment of his views on how to regulate scientific debate. At the suggestion of Christina, Queen of Sweden, Descartes laid down the rules to regulate the activities of an Academy that the Queen wished to create in Stockholm.[75] In them no mention is made of closing disputes by merely performing experiments. The Queen, like the King of the Kingdom amidst the desert, had the right of having the final word in settling controversies.[76] Besides, the exclusion of foreigners from the Academy sessions[77] might very well have a metaphorical import in the sense of the 'strangers' who live beyond the mountains and the wastelands in *La recherche*, i.e. the '*curieux*'.

We have, then, discovered that Descartes has proceeded to an analysis of some important elements of the incipient experimental culture of continental Europe of the first half of the seventeenth century. If our assessment of *La recherche* and the relevant parts of his correspondence is right, we can conclude that the issue over experimentalism did not first arise in the polemic between Boyle and Hobbes. In almost every answer to Mersenne, Descartes remarked on the arguable status of observational reports. And, although his solution to it is different to the one tried by the British experimentalists of the Royal Society, it shares with theirs the conviction that controlled observational reports are essential to the scientific enterprise. The difference in the two agendas seemingly lies in how they guarantee the reliability of the experimental reports, not in a Cartesian alleged neglect of them. Although outside the context of our present exposition it would seem rather anecdotal, it is nevertheless important to remark that Descartes rejects 'the opinion of the Englishman (i.e. Hobbes) which has it that the reflexion of bodies only occurs because they are repulsed, as if by elasticity, by the other bodies that they encounter', not by proposing a theoretical explanation, but suggesting experimental refutations.[78] Perhaps Hobbes' objections to the experimental programme of the Royal Society might have had their origin in the debate that Descartes' letters caused in the Mersenne circle.

Notes

1 I owe my gratitude to Stephen Gaukroger for having so warmly encouraged my work with his decisive comments on earlier versions of this paper. I wish to express too my gratitude to the John S. Guggenheim Foundation for having supported my research with a fellowship. My special thanks also to the Fundación Antorchas (Buenos Aires) and the Universidad Torcuato Di Tella (Buenos Aires) for their invaluable help to this project.
2 Desmond M. Clarke, *Descartes' Philosophy of Science* (Manchester, 1982), 32.
3 Steven Shapin and Simon Schaffer, *Leviathan and the Air-Pump. Hobbes, Boyle, and the Experimental Life* (Princeton, 1985).
4 Bruno Latour, *We Have Never Been Modern* (Cambridge, Mass., 1993), 15–35 et passim.
5 AT x. 489–532.
6 This is the view of Ernst Cassirer in his papers on *La Recherche*, for instance, 'Descartes' *Recherche de la vérité par la lumière naturelle*', in *Descartes. Lehre. Persöhnlichkeit. Wirkung* (Stockholm, 1939), 119.
7 That *La Recherche* has a pedagogical scope is the main thesis of Cassirer's interpretation. See ibid. 125–6.
8 AT x. 499.
9 AT x. 502: 'On the contrary, Poliandre, I think it is you who will benefit from it, since you are not prejudiced, and it will be far easier for me to set someone neutral on the right track than to guide Epistemon, who will often take up the opposite position.'
10 AT x. 504.
11 Steven Shapin, *A Social History of Truth. Civility and Science in Seventeenth-Century England* (Chicago, 1994).
12 Ibid., 78.
13 Ibid., 79.
14 Ibid., 81.
15 Ibid., 120.
16 AT x. 511.
17 AT x. 511.
18 AT ix.16.
19 AT x. 511.
20 AT x. 512.
21 AT x. 512.
22 AT x. 504: 'For my part, I am a little more curious, and I should like you to go on to clarify for me some special difficulties which I find in every science, and chiefly those concerning human contrivances, apparitions, illusions, and in short all the marvellous effects attributed to magic.'

23 AT x. 500.
24 AT x. 502.
25 AT x. 503.
26 AT x. 502–3.
27 AT x. 502.
28 AT x. 523: 'But he must take care not to let himself be deceived or to make the mistake for which he reproaches others, i.e. to regard his esteem for you as a convincing reason for believing what you say.'
29 AT x. 523.
30 AT x. 502: 'I shall be pleased to be present at this discussion, though I do not think myself capable of deriving any profit from it'. See also AT x. 499.
31 AT x. 515.
32 AT x. 515.
33 AT x. 515–6.
34 AT x. 518.
35 AT x. 524: '*Atqui, quoniam eum judicem elegimus, ecquid unquam, quid hoc sit, ignoraverit, ipsummet interrogemus*'.
36 AT x. 522: '*Lubens id equidem hac vice in me suspicio, sed ea sub conditione, ut nostrae litis judex sis*'.
37 AT x. 524.
38 AT x. 527.
39 AT x. 501.
40 AT vi. 30.
41 See Stephen Gaukroger, *Descartes. An Intellectual Biography* (Oxford, 1995), 111.
42 AT x. 501.
43 AT vi. 31.
44 Descartes to Balzac, 5 May 1631, AT i. 203; to Elizabeth, 21 July 1645, AT iv. 252; to Chanut, May 1648, AT v. 183.
45 Op. cit., 188.
46 AT x. 500.
47 AT vi. 73.
48 Descartes to Mersenne, March 1636, AT i. 339.
49 AT i. 81–2.
50 AT i. 203.
51 AT i. 23.
52 Gaukroger, op. cit., 181.
53 Ibid., 188.
54 Ibid., 219.
55 Descartes to Mersenne, 13 November 1629, AT i. 70.
56 Descartes to Mersenne, 11 March 1640, AT iii. 41; to Mersenne, 1 April 1640, AT iii. 50.
57 Descartes to Mersenne, 29 June 1638, AT ii. 189.
58 Descartes to Mersenne, 30 April 1639, AT ii. 533–4; to Mersenne, 15 November 1638, AT ii. 445. See also Constantijn Huygens to Descartes, 2 February 1638, AT i. 509: '*Italiens qui faciunt non intelligendo*'.
59 AT iv. 115. My emphasis.
60 AT i. 160.
61 Ibid., AT i. 161.
62 Descartes to Constantijn Huygens, 5 October 1646, AT iv. 516–7.
63 Descartes to Mersenne, 30 July, 1640, AT iii. 122.
64 Descartes to Mersenne, April 1634, AT i, 287; see also AT i. 341.
65 Descartes to Meyssonnier, 9 January 1640, AT iii. 20–1; to Mersenne, 1 April 1640, AT iii. 49; to Mersenne, 30 July 1640, AT iii. 121.
66 AT i. 70.

67 Descartes to Mersenne, end of November 1633, AT i. 271–2.
68 Descartes to Mersenne, 9 February 1639, AT ii. 499.
69 AT ii. 489.
70 Descartes to Mersenne, 18 December 1629, AT i. 84 and 97; to Mersenne, January 1630, AT i. 113.
71 Descartes to Mersenne, 23 December 1630, AT i. 195–6; to Mersenne, 18 December 1629, AT i. 85.
72 AT x. 503.
73 AT x. 506.
74 AT x. 512–3.
75 'Projet d'une Académie à Stockholm' (1st. February 1650), AT xi. 663–5. According to a letter of Saumaise to M. de Flessel, Viscount of Bregi, the Academy started its activities the Sunday after Descartes' death. See AT v. 476–7. I wish to express my gratitude to Stephen Gaukroger for having drawn my attention to this project.
76 AT xi. 664–5, art. IX.
77 AT xi. 663. See also A. Baillet, *La vie de Monsieur Des-Cartes,* ii. 411–3. Quoted in AT xi. 665.
78 Descartes to Mersenne, 18 March 1641, AT iii. 338–9.

14 Descartes, experiments, and a first generation Cartesian, Jacques Rohault

Trevor McClaughlin

Why did Jacques Rohault, the foremost Cartesian natural philosopher in Paris in the decades immediately following Descartes' death, choose to give experiments pride of place in his work? Why, for that matter, did he emphasise the probabilistic nature of scientific explanation? Cartesian science as exemplified by Rohault's system of natural philosophy was empirically oriented – not the a priori, purely rationalist enterprise which philosophy text-books and first-year university philosophy courses would have us believe.[1]

Equally interesting is the question why Rohault chose to include so much empirical detail in his work. Desmond Clarke, Stephen Gaukroger and others have stressed how much empirical work there is in the writings of Descartes himself. Perhaps historians of philosophy are too obsessed with the later, more metaphysical, Descartes to the neglect of the earlier, more 'scientific', Descartes. An indication of the continuing influence of the one-eyed view of Descartes may be seen in the number of books published on Descartes' metaphysics. It is as if the *Traité de l'Homme, Principia* and *Passions de l'âme* do not exist. Rohault had a rounded, not a one-eyed view of Descartes. He drew on the early works as well as the later ones, so it is important to ask why Rohault felt obliged to flesh out his system of natural philosophy with experiments, and how experiments fitted into his natural philosophical enterprise – how he managed the role of experiment. Just how complex the interrelated social and intellectual forces and opportunities shaping and motivating Rohault's version of Cartesian experimentalism were, is also worth stressing, particularly since relatively naive historical accounts about the origin and essence of seventeenth-century experimentalism have gained so much currency in recent times. Should we look to mainly intellectual conditions for an explanation of Rohault's emphasis on experiments, the influence of Descartes, for example? Or to historical context? What explanatory weight do we attach to the threat of ecclesiastical and state censorship, or Rohault's expropriation of the culture of artisans and craftsmen? What influences made Rohault go in this direction? Was he much influenced by the growth of experimentalism among natural philosophers throughout Europe?[2] This movement was not simply an English or a French phenomenon. It drew its strength from a Europe-wide base.

Let us begin by demonstrating the importance of experiments in Rohault's work. But perhaps we should first say something about the man himself. Jacques Rohault was born in Amiens, most probably in 1617, of solid bourgeois stock. His father and grandfather were both respectable 'bourgeois d'Amiens'. Rohault himself became a Master of Arts of the University of Paris, in 1646,[3] and in the 1650s, befriended the libertine and fantasy/fantasist author, Cyrano de Bergerac.[4] He later became a mathematics teacher to the aristocracy, notably the young Princes de Conti.[5] With the success of his weekly *conférences*, held in his home in Paris during the last fourteen years of his life (1659–72), he was the most prominent exponent of Cartesian natural philosophy in that city. He was lavishly praised by many of his contemporaries, by Claude Clerselier, the inheritor and editor of Descartes' papers, as one might expect, but also by Henry Oldenburg, the secretary of the English Royal Society, and by Christiaan Huygens and Florin Périer, among others. In 1659, for example, Henry Oldenburg wrote to his friend Saporta,

> At Mr Rohault's vision has lately been under consideration; so many fine things were uttered that a whole treatise, not a letter, would be needed to relate them . . . all . . . was handled so precisely and clearly that there was no room for doubt.[6]

At a slightly later date, Florin Périer, executor of the famous Puy-de-Dôme experiment, was to praise Rohault, a kindred spirit, for his '. . . *adresse merveilleuse pour trouver des expériences et pour les expliquer*'.[7] And no less a figure than Malebranche wrote of his prowess in debate,

> . . . everybody knows how justly and how forcefully this scholar repelled the blows aimed at him and with one or two words, uttered calmly and calculatedly, he destroyed the imaginative objections to those who, full of themselves, thought they were able to confuse him.[8]

Rohault was known for his experimental dexterity among the Parisian scientific elite, and it seemed for a time that he might be chosen as a founding member of Louis XIV's Royal Academy of Science. Alas, his promotion of Cartesianism was probably enough to cost him a place; in the 1660s Descartes' works were vehemently opposed on scholastic, theological, and political grounds. In the years before his death in 1672, Rohault became embroiled in a politically dangerous defence of Descartes' religious orthodoxy.[9] On Christmas Eve, 1671, the Archbishop of Paris, François de Champvallon, told Clerselier that he and Rohault should bring to an end their campaign promoting Descartes' interpretation of the Eucharist.[10] Clerselier was later to recount how Rohault, on his death-bed, was interrogated by Nicholas Blampignon, Curé de Saint Médéric, '*en présence de toute la compagnie qui assista à cette pieuse et triste ceremonie, sur les principaux articles de nostre croyance*',[11] and asked to make a public declaration of his Catholicity, confirming his belief that in the Eucharist there was a real transubstantiation of the bread and wine into the body and blood of Christ.

By 1671, however, Rohault's reputation was assured with the publication of an encyclopaedic text which sought to flesh out the experimental details of the Cartesian system of natural philosophy, entitled *Traité de Physique*. Between 1671 and 1739 this work was reprinted more than 25 times[12] and, ironically, was the means by which Isaac Newton's philosophy made headway at Cambridge University. In gradual stages, by way of successive editions of Rohault's *Traité* (1697, 1702 and 1723) Samuel Clarke expanded his Newtonian footnotes to the point where Cambridge students were reading a Cartesian text which was substantially contradicted by its footnotes.[13]

After this thumbnail biographical sketch, let us return to Rohault's scientific work. What is most striking to the present writer is the way Rohault built on the work of Descartes, choosing to emphasise a sophisticated, complex, and probabilistic methodology and choosing to give Cartesian natural philosophy experimental legitimacy. What Descartes wrote about experience, experiments, and hypotheses is well known; so perhaps there is no need to go into that in any detail here. On the other hand, the reader may not be so familiar with Rohault. How did Rohault use hypotheses, for example?[14]

In Part 2 of his *Traité* he described how the hypotheses of Ptolemy, Copernicus, and Tycho Brahe explain the appearances of sun, moon, fixed stars and planets. In ch. 24 he reflected upon the three hypotheses in the following manner:

> . . . because we have here proposed 3 notions of the same thing, one of which only can be the true one, we must necessarily reject two of them as false, and retain the other as the only true one.[15]

He then explains why he rejects the conjectures of Ptolemy and Brahe and accepts that of Copernicus. Ptolemy's hypothesis is rejected because it is experimentally and logically falsifiable, and aesthetically displeasing, in the sense that it denies Ockham's razor. It is contradicted by Galileo's observations of the phases of Venus. Moreover, Ptolemy's system, instead of being deduced from a small number of propositions, is cluttered with a great number 'which are made upon all occasions'.[16] Tycho's hypothesis is better than that of Ptolemy and 'accounts very well for the apparent phases of Venus'.[17] But it cannot be reconciled with reason since the two motions it supposes are contradictory. According to the laws of nature, the motion of the 'matter of the planetary heavens' must gradually diminish and stop because it must be imparted to the celestial matter (i.e. of the starry heavens) which is gradually being turned out of its place.[18] Copernicus' hypothesis, Rohault declares, is the true one for it provides the simplest explanation of the phenomena and is supported by experiment.

'After these explanations', says Rohault,

> we shall make no difficulty of joining with one party, and declaring for the hypothesis which is commonly called Copernicus'; so that when we mention our hypothesis hereafter, we are to be understood to mean this, which in all our philosophy we shall suppose to be the true one.[19]

This is, of course, not the only way Rohault uses hypotheses, but it is nonetheless a very clear and candid statement that in astronomy 'one can only proceed hypothetically'.[20] Incidentally, in a *Fragment de Physique* written by Rohault's celebrated pupil, Cyrano de Bergerac,[21] provision is made for defending the proposition that physics is a conjectural science, a reflection perhaps of Rohault's scholastic training at the University of Paris or indeed, his interpretation of Descartes' hypothetico-deductive method of scientific reasoning.

What is also not widely known are the ways experiments informed Rohault's system of natural philosophy.[22] Rohault used and built upon the experiments which Descartes described in his *Météores*, *Principes de la Philosophie*, and *Discours de la Méthode*. Many of the experiments contained in Descartes' *Météores*, for example, were included in Part III of Rohault's *Traité*: an experiment with an aelopile to confirm their explanation of winds,[23] an account of Descartes' observations on the shapes of hailstones and snowflakes,[24] an explanation of 'mists' and 'manna', and the use of a glass globe filled with water to explain the properties of the rainbow.[25] Other examples, notably the inspiration of Rohault's discovery of capillary action[26] and his demonstration of the properties of the magnet,[27] may be found in the *Principes*. Rohault reproduced Descartes' experiments with magnets and iron filings, compass needles, '*une pirouete de fer*',[28] '*les pincettes qui servent a attiser le feu*'[29] and two magnets suitably positioned, one of which is situated in '*un petit bateau*',[30] or in Descartes' case, '*une petite gondole*',[31] floating on water. From this, it would appear that Descartes, the master, was a major, if not *the* major, inspiration for Rohault's love of experimentation.

Rohault also used a rich variety of experiments of his own devising, experiments taken from the anatomical work of Asselli, Jean Pecquet, William Harvey, and Nicholas Steno (*capillaments* of a nerve), the dissections by one of the first royal academicians, Louis Gayant,[32] the astronomical observations of Galileo, Jean Dominique Cassini, and Christiaan Huygens,[33] and the experiments on 'the weight of the air', inspired by Blaise Pascal.

He reproduced most of the classic experiments on vacua and nearly all those with water, mercury and air described in Pascal's *Treatise on the Weight of Air*: experiments with bellows, syringes, suction by mouth, respiration, cupping-glasses, siphons, and glass tubes. Roberval's experiment with a carp's bladder and Pascal's two most celebrated experiments, 'Puy-de-Dôme' and '*le vide dans le vide*', were repeated by Rohault and given a Cartesian interpretation.[34]

Rohault repeated Pascal's Puy-de-Dôme experiment by especially commissioning, from a local glassmaker, a Torricelli tube within the vacuum of a large tub of similar design and then conducting experiments of his own, comparing measurements taken on the bank of the Seine with those taken at the top of the towers of Nôtre-Dame.[35] In this instance, as elsewhere, he may have allowed Cartesian theory to predetermine how he interpreted his experiments. But Rohault always insisted that sound interpretation of experiments depended on an underlying theoretical model, in his case, a Cartesian one. Descartes would always be the major influence on the way he interpreted his experiments. Where Shapin has, somewhat questionably, depicted Boyle as originating Experimental Science by stepping outside the realm of natural philosophy and its conflicts, Rohault was a participant in, an actor in the natural philosophy of his day, as indeed was Boyle.[36] For Rohault, the ascendancy of Descartes' system of natural philosophy was something worth struggling for and something to which he was utterly devoted.

In a celebrated preface to his *Traité*, Rohault identified three kinds of experience:

> The first is, to speak properly, only the mere simple using our senses; as when accidentally and without design, casting our eyes upon the things around us, we cannot help taking notice of them, without thinking of applying what we see to any use.[37]

This is the case with immediate sense experiences: a ball struck by a racket which he later used to show that determination differs from motion, for example, or the colour blindness of his right eye which he used to demonstrate that 'two persons looking in the same manner upon the same object may have very different sensations'.[38] The second sort:

> is, when we deliberately and designedly make tryal of any thing, without knowing or foreseeing what will come to pass; as when after the manner of chymists, we make choice of first one subject and then another, and make all the tryals we think of upon each of them. . . . We also make experiments in this second way, when we go amongst different sorts of workmen in order to find out the mysteries of their arts, as glassmakers, enamellers, dyers, goldsmiths, and such as work different sorts of metals.[39]

Presumably, this second sort includes his experiments with '*larmes de verre*',[40] his '*experience continuelle du vuide*',[41] his description of the peculiarities of dyeing cloth black,[42] and the method of separating gold from silver.[43] Lastly, the third sort of experiments:

> are those which are made in consequence of some *reasoning* in order to discover whether *it* was just or not. As when after having considered the ordinary effects of any particular subject, and formed a true idea of the nature of it, that is, *of that in it which makes it capable of producing those effects*; we come to know by our reasoning, that if what we believe concerning the *nature* of it to be true, it must necessarily be, that by disposing it in a certain manner, a new effect will be produced, which we did not before think of, and in order to see if this reasoning holds good, we dispose the subject in such a manner as we believe it ought to be disposed in order to produce such an effect. Now it is very evident that this third sort of experiments is of peculiar use to philosophers, because it discovers to them the truth or falsity of the opinions which they have conceived.[44]

This third sort, the most important of all, as Desmond Clarke points out, are experiments, designed on the basis of Cartesian theory, that Rohault used to test the implications of his hypotheses and helped him confirm or disconfirm their plausibility. Presumably these include his experiments in optics, with an artificial eye made from cardboard, vellum, glass and crystal, experiments in physiology, 'to shew the course of the chyle in the body'[45] and to confirm the circulation of the blood,[46] as well as his experiments in hydrostatics and magnetism, with glass tubes, iron filings and compasses. We should be clear, however, that Rohault's experiments tested particular hypotheses of Cartesian type. They were framed in terms consistent with, but not typically deducible from, fundamental principles. Rohault held that there may exist different detailed models consistent with such principles and thus needing to be weeded out by such testing on a probabilistic basis. As John Schuster has put it,

> Rohault held that a corpuscular-mechanical explanatory model is more probable to the degree that it has been formulated by consideration of fewer properties of the *explicandum*, and can be extended to cover new experimental phenomena. This, however, is not a modern hypothetico-deductive method, because Rohault insisted that such hypothetical models be consistent with, and controlled by, unquestioned basic principles of the mechanical philosophy, in its Cartesian form.[47]

At the very least, Rohault, in the words of Desmond Clarke, clearly 'understood the importance of a technically well-designed test'.[48]

Rohault's proficiency with scientific instruments is verified not only by Claude Clerselier, who praised his son-in-law's '*esprit tout à fait mécanique*' and the pleasure he gained in frequenting the workshops of artisans. Clerselier talks of Rohault's

> mechanical mind, just right for inventing and imagining all sorts of techniques and machines, and at the same time, skilful artisan's hands that enabled him to execute all that his imagination dreamed up. So he took pleasure in going to the workshops of all sorts of workers, to watch them work at their craft, and to study with great care the different tools they used in their work.[49]

It is independently verified by a post-mortem inventory of the instruments in Rohault's possession at the time of his death, drawn up by the notary Claude Ménard, 27 February 1673.[50] The scientific instruments in Rohault's possession at the time of his death correspond exactly to those areas where Rohault concentrated his experimental efforts, namely, optics, magnetism, and vacua or, as Rohault would have put it, 'the weight of the air'. Moreover, some of these instruments, '*oeil artificiel de carton, boîte pour expliquer la refraction, "chambre de Rohault", etc.*' were the product of Rohault's own mechanical ingenuity[51] and of his fruitful relationship with artisans and craftsmen. But more of his relationship with artisans later.

To return to the question posed at the beginning of this chapter: why did Rohault put Descartes' work in natural philosophy on an experimental footing? Was it simply a question of following Descartes' exhortation to his followers to fill in the experimental details of his system? In turning attention to those parts of Descartes' works which show how much empirical work Descartes had actually done, Rohault, like many other French Cartesians in the second half of the seventeenth century, came to appreciate the complexities of Descartes' method of scientific explanation. Like the few who engaged in experimental work – Pierre-Sylvain Régis comes to mind – he came to an explicit recognition of the hypothetico-deductive structure of scientific explanations.[52] For some, this intellectualist explanation may be an adequate explanation of what happened. But it will not be enough for those who want a deeper historical understanding of Rohault's experimentalism.[53] It is important, then, that we explore the historical context of actors in the so-called 'Scientific Revolution'. To look, for example, at the ways non-intellectual conditions affected the work of people like Rohault, rather than questions of what he 'really' meant or how logical or 'correct' he was in his interpretation of Descartes. In Rohault's case, we should acknowledge the need to create a fully rounded historical figure. And to do this we need to know and understand the context in which he lived and worked. What then of Rohault's particular case? We know, for example, that Rohault cared for and manipulated his quality instruments with all the flair of an innovative craftsman. This seems to me an extremely important consideration. His ability to design and work with such instruments[54] encouraged the development of his experimental skills. Rohault was taking advantage of his own mechanical skills, as well as recruiting powerful resources in favour of his version of Cartesian natural philosophy. According to Claude Clerselier, he took great pleasure in visiting artisans in their workshops and even giving advice on how their tools might be improved. Whether the pleasure was reciprocated by those same artisans is another matter.

In his *Traité* Rohault did indeed make use of his experience of the techniques of artisans to illustrate many of his arguments and to demonstrate the experimental validity of his Cartesian principles. The evidence available suggests that it was through family connections that he gained such experience. Rohault's first wife was a widow by the name of Nicole Filassier whom he married in 1650. From signatures to legal documents in the Minutier Central, we know that Rohault had connection with Philippe Filassier, marchand orfèvre de Paris, Michel Filassier, marchand jouaillier, and Jean Le Paultre, maistre maçon de Paris, among others. In his *Traité* Rohault wrote of gold-workers and the divisibility of matter,[55] the means of separating gold and silver,[56] how goldsmiths make silver white,[57] why gold is easy to cut,[58] of diamonds and the properties of light,[59] of precious stones,[60] how water hardens plaster of Paris, and of lime and the properties of heat.[61]

Clearly, Rohault borrowed from the techniques of artisans and marshalled an expert stock of knowledge which was accessible to him, all in the cause of Cartesian experimentalism. His family network of stonemasons, goldsmiths, and jewellers is directly linked to the experiments he performed in his weekly *conférences* and the experiments he described in his *Traité*. Indeed it may not be too far-fetched to claim that Rohault's unacknowledged borrowing from the techniques of craftsmen is a good example of a bourgeois natural philosopher expropriating the 'secrets' of artisan culture. Rohault made those 'secrets' serve his own experimentalist promotion of Descartes' system of natural philosophy.

Equally interesting from the viewpoint of exploring the complex interplay of influences on Rohault was his relationship with his father-in-law, Claude Clerselier. Gaukroger rightly identifies the remoteness of culture between writer and subject as one of the problems facing biographers. One may add, historians as well. The nature of France's social structure in the early years of Louis XIV's reign, the social pressures and opportunities for someone like Rohault, the son of a provincial bourgeois, to climb the social ladder in a youthful and vibrant capital city, Paris, and the crucial role of patronage in this process, are all things we neglect at our peril.[62] This is the unappreciated social context of the relationship between Rohault and Clerselier. Clerselier was, in effect, Rohault's patron. It was a relationship which did not always work to Rohault's advantage.

Clerselier was the older of the two men, a member of the minor aristocracy, a Parlementarian of Jansenist leanings, and in 1664, he overrode his own family's objections to the marriage between Rohault and his youngest daughter, Geneviève. If Adrien Baillet is to be believed,

> All the relatives of the young lady, with the exception of her father, were much displeased with this mismatch; and even the new son-in-law having taken their side, had tried to get out of it. But nothing could defeat M. Clerselier, who finding his daughter ready and willing to obey him and very happy with the match, was determined to push this marriage through solely out of consideration for the philosophy of M. Descartes.[63]

Clerselier[64] was also friend and correspondent of Descartes, the saviour and inheritor of Descartes' papers, and translator and editor of Descartes' works.[65] For each of these reasons Rohault would forever be in Clerselier's shadow. He would always defer to him and look to him as patron, patriarch, guide and mentor.

In the 1650s and 1660s Descartes' works were increasingly subjected to criticism by more orthodox philosophers and theologians. In their view, rightly or wrongly, Descartes' methodological doubt encouraged a dangerous scepticism. Even worse, his philosophical principles were tainted with religious heresy. Clerselier took up the cudgels in Descartes' defence with such energy as to invite censorship. And he dragged Rohault into this very dangerous battleground of theological and political controversy, by making him defend Descartes' interpretation of the Eucharist. The question needs asking whether Rohault sought solace in the relative safety of experimental physics, pushed in this direction by the ever growing threat of censorship?

However far-fetched such a conjecture appears to be, it is worth considering. There is some evidence, for instance, that the newly founded Académie des Sciences sought refuge in experimental science precisely because it wanted to avoid involvement in political and theological affairs.[66] The English Royal Society was no different from its French cousin in this respect.

On the other hand, Rohault was an experimental physicist before Clerselier's campaign in defence of Descartes' religious purity had gained momentum. The timing is crucial. However important the growth of Louis XIV's absolutism, Jansenist controversy, and the entrenched conservatism of School philosophers may be for the dissemination and acceptance of Descartes' philosophy in France, it must be conceded that they had considerably less direct an influence on Rohault's attempt to legitimize Descartes' natural philosophy by putting it on an experimental basis. Yet if such a political and religious climate does not explain the origins of Rohault's attempt, might it have helped him confirm that this was the correct thing to do? We may surmise, and it is only conjecture, that Rohault used experiments as 'barriers' which he erected to help him separate theology from natural philosophy, and align himself with the more progressive elements in the Parisian scientific community.

A more appropriate instance of the way historical context had a direct impact on Rohault's experimentalism concerns Parisian scientific assemblies and the fledgling royal Academy of Science. Rohault played an active role in the Parisian *conférence* milieu of the late 1650s and 1660s.[67] By the 1660s Descartes' philosophy in general may have gained ground throughout the educated world. But his natural philosophy was far from being universally accepted, especially in France. Samuel Sorbière, for example, was to complain of Habert de Montmor's academy that 'each person wants to see his own sect, his own principles, or his own hypothesis ruling the assembly'.[68] The sceptics, he said, enjoyed listening to this cacophonous 'symphony composed by a Peripatetic, a Lullist, a Cartesian, a Chemist, a follower of Plato, a friend of Lucretius and several other philosophers'.[69] Cartesians, in effect, were only one school among many. Clerselier may have been the leader of that loosely grouped Cartesian school committed to the propagation and defence of Descartes' philosophy. But Rohault was its champion of Descartes' natural philosophy, a cause which he promoted using his experimental skills to best advantage.

Rohault, Clerselier, Cordemoy, Fédé and others of like mind outspokenly promoted the Cartesian cause at the weekly *conférences* of Habert de Montmor, the Abbé Bourdelot and at Rohault's, in the Rue Quincampoix, where his appeal to experimental illustrations and successful applications of Cartesian theory, rather than deductive metaphysical argument, won him a well-deserved reputation. For instance, a young Christiaan Huygens, in a visit to Paris in 1660, recorded in his diary:

> 7 dec. 1660 at Montmor's assembly . . . Rohault read his experiments on water rising in thin glass tubes . . . 14 dec Rohault explained the phenomenon of water rising in thin glass tubes . . . 28 dec Chez Montmor, dispute between Rohault and Auzout.[70]

Rohault's *conférence* technique, according to Clerselier,[71] was to give a talk on problems in physics for about an hour, establishing his principles and proving them by demonstrated experiments. With an admirable moderation and patience he permitted interruptions to his discourse, answered any objections, took up the argument again and completed what he set out to do. The many people who came to his *conférences* from all walks of life were especially impressed with Rohault's experimental demonstrations. Among the most remarkable were those on the 'weight of air', in particular, one performed with an instrument of his own invention '*semblable à peu prés à la figure dont les Anatomistes se servent pour representer la grande Artere ascendante et descendante*',[72] experiments on light, notably the demonstration of Descartes' explanation of the rainbow by means of an artificially created rainbow projected on to a screen, and finally, those on the properties of the magnet, for which he had a special box of materials '*d'où il tiroit chaque piece l'une aprés l'autre, selon l'effet ou la proprieté qu'il vouloit prouver, et l'experience que pour cela il avoit à faire*'.[73] Rohault would have been aware that a politically motivated rhetoric of empiricism in natural philosophy, in France as in England, was a means of distinguishing between those on the 'outer' and those riding high on the wave of royal recognition and reward.

Given his reputation as an experimentalist in salon society, and given the Royal Academy's utilitarian emphasis and almost Baconian programme of research in its early years,[74] Rohault must have harboured ambitions of becoming an academician. It was certainly in his interest to portray himself as a practical, experimental natural philosopher. His hopes were soon dashed however. When Montmor's academy collapsed in 1663 Rohault did not follow his fellow experimentalists to Melchisédech Thévenot's Company des Artz, a company which was to play such a crucial role in the foundation of the French Royal Academy of Science. By then Rohault had become estranged from certain influential members of the 'scientific' community. Adrien Auzout, who was a prominent member of both Thévenot's and the Academy of Science from its inception, was an avowed enemy of Rohault and strong enough to exclude him from both assemblies. Jean Chapelain, a member of the '*petite académie*' and one of Colbert's advisers on the choice of members for the Académie des Sciences, detested Descartes' disciples to the point of excluding them from the pension lists. Rohault's high profile as leader of a Cartesian 'sect' was enough to exclude him from a body which found it politic not to support any one system of natural philosophy and whose patron, Louis XIV, publicly opposed Cartesianism.[75]

Nonetheless, by the time Rohault came to write his *Traité de Physique,* in the years immediately preceding its publication in 1671, he must have known that he would not be called to the Academy. Once again, chronology, the timing of events, is all important. When he wrote his *Traité,* he must have known he had little chance of becoming a member of the Royal Academy of Science. Yet he persisted in fleshing out the experimental details of Descartes' system. There is, in other words, no simple political account of Rohault's experimentalism. Let me finish by reviewing the complexity of motives and contexts for Rohault's experimentalism. The reader will appreciate the Rohault example has significance beyond its own immediate particularities.

First, Descartes' views on method exhibit 'a fascinating chiaroscuro' – the phrase is Gerd Buchdahl's[76] – of the two ways of scientific reasoning, and there is much empirical work in his texts and letters, readily available for anyone looking for such things. Descartes was undoubtedly a major influence on Rohault, both encouraging him to promote 'mechanical explanations which were unavoidably hypothetical' and providing him with experimental building blocks in his *Météores, Dioptrique, Principes de la Philosophie* and *Discours de la Méthode*. The interesting question is why Rohault should read Descartes in this particular way.

By the accident of birth and marriage, Rohault developed an encouraging and creative relationship with artisans and craftsmen. Such a relationship not only educated him and widened his horizons, it honed his mechanical skills and gave him access to high quality instruments. As one among many actors in a Europe-wide culture of natural philosophy Rohault was able to rely on much more than a 'gentlemanly code of trust'. He drew on a wide range of expertise: the scholastic language and training of his university days; the mechanical skills of artisans; his own reading of Descartes, made easier by his access to Descartes' papers through the inheritor of those papers, his father-in-law, Claude Clerselier; not to mention his openness to the experimental work of his contemporaries, Pascal, Huygens and a host of others which he used to flesh out his Cartesian system of the world.

Clerselier's patronage and social network helped Rohault climb the social ladder. It opened doors for him which would otherwise have remained closed. Yet it also dragged him into political and theological controversy. In the 1660s Clerselier had reacted to the condemnation of Descartes by political and religious authorities in a positive yet dangerous way. He insisted that Descartes' interpretation of the Eucharist, far from being heretical, was in the tradition of St Augustine and the Church Fathers; that far from threatening dogma and peace it could be used to win over Protestants and reconcile the Eastern and Roman churches. At Clerselier's behest Rohault became embroiled in the political and theological defence of his master. Paradoxically, Clerselier's patronage both strengthened Rohault's reputation as the pre-eminent Cartesian natural philosopher of his day, and at the same time, because of 'political incorrectness' over the Eucharist and Beast-Machine controversies, weakened his chance of attaining the success he coveted most. There is little doubt that his very public espousal of Cartesianism kept him out of the Académie des sciences. He inescapably had become embroiled in a political and religious defence of Descartes. His career and work in natural philosophy cannot be divorced from this historical context.

Finally, of great importance was the strong experimental tradition which existed among natural philosophers in France in the mid-seventeenth century. Men like Fabry de Peiresc, Marin Mersenne, Boulliau, Chapelain, Sorbière and Henri Justel regularly spread news of experiments in England, Italy, the United Provinces, Germany, Denmark and Sweden. Letters, books, broadsheets and pamphlets circulated among scholars, secretaries of academies and editors of Journals. In the 1640s and 1650s repetition and analysis of Pascal's Puy-de-Dôme experiment was taken up by a whole range of French natural philosophers – Mersenne, Chanut, Descartes, Pierre Petit, Florin Périer, Roberval, Gassendi, Auzout and Marriotte, to mention a few. Rohault, a creature of his times, was willing to develop his interest in experiments buoyed by this experimental tradition, by his own 'rounded' reading of Descartes and, closer to home, in the 1650s and 1660s, by the ascendancy of experimentalists in Paris salons, private assemblies and the young Royal Academy. The Parisian 'scientific' community at Montmor's, Thévenot's, Bourdelot's and the nascent Academy of Science encouraged him in this direction. The rhetoric of the natural philosophy experimental lobby, in France as in England and elsewhere, made it a potent political and intellectual force and Rohault did well to heed its call.

Rohault drew on a complex interplay of motives and opportunities to develop his experimentalism; a family background which gave him access to the workshops of artisans, his own mechanical talents and dexterity, a 'scientific' community which held experimental skills in high regard, and above all, the influence of his master, René Descartes. Desmond Clarke has shown how Rohault, along with other Cartesians such as Pierre-Sylvain Régis, Claude Gadroys, Nicolas Poisson and Louis de La Forge, were recognised as 'leading proponents of an unrestricted use of hypotheses in scientific explanations'[77] and moreover, that the experimental significance of hypotheses was far more influential on Cartesian 'scientific' practice than the attempt to derive certain principles from metaphysical foundations. In fitting into this mould and in keeping with his own specific historical context, Rohault read Descartes very much in tune with contemporary natural philosophical trends: he deployed a rhetoric of experiment and appropriated, to his cause, large collections of existing matters of fact as well as experimental 'hardware' and skills.

Notes

1 The author's perception of this question is much influenced by a reading of Gerd Buchdahl, Stephen Gaukroger, and Desmond Clarke. In particular, Desmond Clarke's two works, *Descartes' Philosophy of Science* (Manchester, 1982), and *Occult Powers and Hypotheses: Cartesian Natural Philosophy under Louis XIV* (Oxford, 1989) offer a persuasive and attractive analysis of the role of experience, and of hypotheses, in Cartesian natural philosophy.

2 See T. McClaughlin, 'Was there an empirical movement in mid-seventeenth century France?', *Revue d'Histoire des Sciences,* vol. 49 (1996), 459–81.

3 Bibliothèque Nationale, Fonds Latin 9154 fol 77.

4 Cyrano de Bergerac, *Histoire Comique ou Voyage dans la Lune* (Paris, 1657), preface by Henri Lebret, not pag.

5 *Oeuvres Posthumes de Mr Rohault,* preface by Claude Clerselier, not pag. and Archives Nationales R* 274 Compte de Madame, fol 25 and A. N. R* 276 Compte de Madame 1669 fol 23vo.

6 *The Correspondence of Henry Oldenburg*, ed. and trans. A.R. and M.B. Hall, 9 vols (Madison, 1965–73), i. 287.

7 B. Pascal, *Traité de l'Equilibre des Liqueurs*, 2e édit. (Paris, 1664), preface, not pag.

8 *Oeuvres de Malebranche*, gen. ed. André Robinet, 20 vols. (Paris, 1958–62), *Préface contre Le Livre de Foucher*, ii. 497.
9 The religious and political context of Rohault's later years is clearly set out in Clarke, *Occult Qualities*, ch. 1, T. McClaughlin, 'Censorship and defenders of the Cartesian faith in mid-seventeenth century France', *Journal of the History of Ideas*, vol. 40 (1979), 563–81, and T. McClaughlin, 'Claude Clerselier's attestation of Descartes's religious orthodoxy', *Journal of Religious History*, vol. 20 (1980), 136–46.
10 Clerselier to Desgabets, 6 Jan 1672, Epinal Mss 43, 282–3.
11 *Oeuvres posthumes*, preface, not pag.
12 The best account of the various editions of Rohault's *Traité de Physique* is found in M.A. Hoskin, 'Mining all within: Clarke's notes to Rohault's *Traité de Physique*', *The Thomist* vol. 24 (1961), pp. 353–64, p. 353 note 4. Here is the list of editions with a few minor changes of my own: **French editions, published in Paris**: 1671 (1st edn.), 1672 (2nd edn.), 1676/5 (3rd edn. corrigée), 1676 (4th edn. reveüe et corrigée), 1682 (4th edn. très exactement reveüe et corrigée), 1705, 1708 (12th edn.), 1723, 1730. **French editions published in Amsterdam**: 1672, 1676. **Latin translation by Bonet**: 1674, Geneva; 1682, London; 1682, Amsterdam, with notes of Le Grand; 1700, Amsterdam, with notes of Le Grand. **Latin translation by Clarke** and with his notes: 1697 (1st version of notes), London; 1702 (2nd version), London; 1708 (2nd version, with notes of Le Grand), Amsterdam; 1710 (3rd version), London; 1713 (2nd Latin edn. of 'Mechanics' etc., with notes of Le Grand), Cologne; 1718 (3rd version), London; 1739, '6th edition', Leiden. **English translation of John Clarke** with 4th version of Samuel Clarke's notes: 1723, London; 1728/9, London; 1735, London. Poggendorff mentions an edition with Clarke's notes printed in 1701 and the *Allgemeines Buche-Lexicon* (Leipzig, 1793) mentions another, with Clarke's notes, published at Leiden in 1729. G. Varet, *Manuel de Bibliographie Philosophique*, 2 vols (Paris, 1956), i, 376, adds *Traité de Physique*, 4th edn., Paris, 1681 and describes the *Traité de Physique*, 12th edn., Paris and Bruxelles, 1708, as a 'faux'.
13 It is the 1671 Paris edition and a facsimile reproduction of Clarke's 1723 edition which have been used in the preparation of this paper: Jacques Rohault, *A System of Natural Philosophy*, trans. John Clarke, ill. with Dr Samuel Clarke's notes, 2 vols (London, 1723).
14 See Clarke, *Occult Powers*, ch. 5.
15 Rohault, *System*, II, 24, p. 59.
16 Ibid, p. 60.
17 Ibid, p. 61.
18 Loc. cit.
19 Loc. cit.
20 Clarke, *Occult Powers*, 156.
21 Appended to the 1662 edition of *Les Nouvelles Oeuvres de Savinien de Cyrano Bergerac*. On Rohault's relationship with Cyrano, see Cyrano's *Histoire Comique ou Voyage dans la Lune* (Paris, 1657), préface de Henri Lebret, not pag. Nineteenth- and twentieth-century editors and critics of Cyrano, such as P. Lacroix, P.A. Brun, and F. Lachévre, have written much about the friendship of the two men but none of it is substantiated.
22 See Clarke, *Occult Powers*, ch 7.
23 *Météores*, Discours IV, AT vi. 265–7, and Rohault, *System*, III, 11, 206–7.
24 AT vi. 293–308, and Rohault, *System*, III, 14, 217.
25 AT vi. 309–10, 325, and Rohault, *System*, III, 14, 217, 15, 219, 17, 225.
26 *Principes* Part IV, arts. 19, 209–10 and Rohault, *System*, I, 22, 140–8.
27 *Principes* Part IV, arts. 133–83 and 271–305, and Rohault, *System*, III, 8, 163–87.

28 *Principes,* ibid. and Rohault, *System,* III, 8, 182–3.
29 Rohault, *Traité,* III, 8, 216.
30 Ibid., III, 8, 210.
31 *Principes,* Part IV, arts. 170, 297.
32 Rohault, *Traité,* IV, 21, 366–7; IV, 6,329; IV,7, 330; IV,5, 327–8; IV, 12, 339; IV, 13, 342–3.
33 Ibid., II, 14, 55; II,16, 61; II, 16, 61–3 and Rohault, *System,* II, 16, 45–6.
34 B. Pascal, *Treatise on the weight of the mass of the air,* in R.M. Hutchins ed., *Great Books of the Western World,* 53 vols (Chicago, 1952) xxxiii, p. 404 sq. and Rohault, *Traité,* I, 12, 97, 72–9, 98, 97–8, 98–9, 95–7, 79 sq., 87–8, 90–2, 92–5.
35 Rohault, ibid., I, 12, 90–1.
36 See S. Shapin, *A Social History of Truth. Civility and Science in Seventeenth Century England* (Chicago, 1995) and the essay review of this work by John A. Schuster and Alan B.H. Taylor, 'Blind Trust: The Gentlemanly Origins of Experimental Science', *Social Studies of Science,* vol. 27(1997), 503–36.
37 Rohault, *System,* préface, not pag.
38 Ibid., I, 13, 79 and I, 27, 197.
39 Ibid., préf.
40 Ibid., I, 22, 136–9.
41 Ibid., I, 12, 72. This experiment lasted for at least fifteen years.
42 Ibid., I, 27, 228–9.
43 Ibid., I, 22, 126.
44 Ibid., préf.
45 Ibid., IV, 21, 283.
46 Ibid., IV, 12, 264–6.
47 See John Schuster, 'Jacques Rohault', in W. Appelbaum, ed., *Encyclopedia of the Scientific Revolution* (New York, in press).
48 Clarke, *Occult Powers,* p. 211.
49 *Oeuvres Posthumes de Mr Rohault,* préface, not pag.
50 Archives Nationales, Minutier Central, Etude XXXIX, Liasse 127.
51 T. McClaughlin and G. Picolet, 'Un exemple d'utilisation du Minutier central de Paris: la bibliothèque et les instruments scientifiques du physicien Jacques Rohault selon son inventaire après décès', *Revue d'Histoire des Sciences,* vol. 29 (1976), 3–20.
52 As Gerd Buchdahl long ago observed, Rohault's hypothetico-deductivism is not of a fully modern type, because Rohault insisted that such hypothetical models be consistent with, and controlled by, unquestioned basic principles of the mechanical philosophy, in its Cartesian form.
53 Incidentally, it is also worth remarking that what subsequent generations have written about Descartes' work or what modern philosophers write about Descartes, today, is for the most part, not directly relevant to the historian's task. (We are not talking here of the 'shadow histories' Richard Watson delineates in the *Journal of the History of Philosophy* vol. 31 (1993), 95–123.) This does not mean that historians fail to appreciate interesting intellectual questions such as thrown up by Peter Dear's *Discipline and Experience* (Chicago, 1995), or Steven Shapin's *Social History of Truth.* Whether Rohault measures up to Peter Dear's ideas about 'mathematical one-off event-experiments being able to warrant general claims' is one such question probably worth pondering. Rohault's work as an experimenter may even be a timely reminder of just how Anglo-centric or localised and mono-causal is much of the recent work on Robert Boyle and the English Royal Society.
54 A reference in his own *Entretiens sur la philosophie* (Paris, 1671), suggests that his mechanical interest manifested itself at an early date. In a conversation with a syndic of the Sorbonne on the Beast-Machine controversy, he refers to '*certains*

automates que j'ay veu dans ma jeunesse et que [sic] representoient fort bien et fort artistement divers animaux' (151).

55 Rohault, *System*, I, 9, 34–7.
56 Ibid., I, 22, 126.
57 Ibid., I, 27, 221.
58 Ibid., III, 6, 155.
59 Ibid., I, 27, 205–6.
60 Ibid., III, 7, 160–1.
61 Ibid., I, 22, 131–2 and I, 23, 163.
62 This social context is something David Sturdy has brought out extremely well in his recent study of *Science and Social Status The Members of the Académie des Sciences, 1666–1750* (Woodbridge, 1995).
63 A. Baillet, *La Vie de Monsieur Descartes* (2 vols, Paris, 1691: facsimile reproduction, Geneva, 1970), ii. 241. The signatories to the marriage contract of 8 Sept. 1664 (A.N. Minutier central de Paris, Etude XXXIX, liasse 110) include, on Rohault's behalf, Jacques Rohault (uncle), Marchand Bourgeois de Paris, Jacques Boulot, Marchand Bourgeois de Paris, Jean le Cuntrix (?), Marchand Drapier, Bourgeois de Paris and on Clerselier's behalf, Catherine Clerselier, wife of Adrien Chanut, Seigneur de La Haye, Martial Chanut, Conseiller et Ausmonier ordinaire de la Royaume et du Roy, Hector Chanut, Conseiller du Roi en son Grand Conseil and Philippe Hurel, Sieur de Neauville, Commissaire des gardes.
64 On Clerselier, see T. McClaughlin, 'Claude Clerselier's attestation of Descartes's religious orthodoxy', *Journal of Religious History*, vol. 20 (1980), 136–46.
65 On the history of Descartes' papers, see Charles Adam, 'Clerselier éditeur des Lettres de Descartes', *Comptes rendus des séances et travaux de l'académie des sciences morales et politiques*, vol. 45 (1896), 722–54.
66 T. McClaughlin, 'Sur les rapports entre la compagnie de Thévenot et l'académie royale des sciences', *Revue d'Histoire des sciences*, vol. 28 (1975), 238–9. For sensible comments on the nascent academy see David Sturdy, *Science and Social Status*, chs 1–4 and ch 10.
67 C. Le Maire, *Paris Ancien et Nouveau* (Paris, 1685), 442–3; Bib. Ste Geneviève Mss 2225, Conférences sur la physique faite en 1660–1 par Jacques Rohault . . .; Samuel Sorbière, *Discours prononcé le 3 avril 1663. A l'ouverture de l'Académie des physiciens, qui s'assemblent tous les mardis chez Monsieur de Montmor*; and Harcourt Brown, *Scientific Organisations in Seventeenth-Century France* (New York, 1934).
68 Bibliothèque Nationale Mss Cinq Cents de Colbert 485, fols 441–5, S. Sorbière, *discours prononcé le 3 Avril 1663. A l'ouverture de l'Académie des physiciens, qui s'assemblent tous les mardis chez Monsieur de Montmor.* Reprinted with a few minor changes in G. Bigourdan, 'Les premières réunions savantes de Paris au 17e siècle', *Comptes Rendus des Séances de l' Académie des Sciences*, vol 64 (1917), 159–62 and 216–18: at 216. The translations are my own.
69 Ibid.
70 *Oeuvres complètes de Christiaan Huygens*, 22 vols (La Haye, 1888–1950), xxii. 539–41.
71 *Oeuvres posthumes de Mr Rohault*, préf., not pag.
72 Ibid.
73 Ibid.
74 Sturdy, *Science and Social Status*, ch. 10, esp. 156–9.
75 Ibid., 140. Sturdy, in writing about the foundation of the Académie des Sciences (75–9), advances the useful suggestion that Colbert was not so much concerned with implementing Perrault's 'grande académie' or Huygens' and Thévenot's plan from the 'Compagnie des Artz' as he was with making a

careful choice of individual savants for his academy. 'It was the savants themselves who were the depository of Colbert's intentions' (77). With this in mind, it may be noted that most of the original members of the Académie des Sciences were either trained technicians or held offices connected with the sciences (Bourdelin was Apothicaire du Duc d'Orléans, Gayant, Chirurgien de Paris et des Armées du Roi, Buot, Ingénieur Géographe du Roi et Professeur de Mathématiques des Pages de la Grande Ecurie, Marchant, Directeur de la Culture des Plantes au Jardin du Roi, and Roberval held the chair of Mathematics at the Collège de France) or else, they were favoured by members of the '*petite académie*' such as Jean Chapelain, Pierre de Carcavi, Adrien Auzout and the Perrault brothers. Rohault belonged to neither clientele.

76 G. Buchdahl, *Metaphysics and the Philosophy of Science: The Classical Origins, Descartes to Kant* (Oxford, 1969), 82–3.

77 Clarke, *Occult Powers,* 131, n. 2.

Part III

Physiology

15 Cartesian physiology

Annie Bitbol-Hespériès[1]

Part V of the *Discours de la Méthode*, published anonymously in 1637 at Leyden, offers the reader 'in particular the explanation of the movement of the heart'.[2] This detailed account (nearly half of the fifth part[3]), which includes Harvey's discovery of the circulation of the blood, is a preeminent example of Descartes' *méthode,* and introduces numerous innovations which illustrate an important aspect of what is at stake in Descartes' medical and physiological[4] research. In the *Dioptrique,* one of the *Essais* which accompany the *Discours*, Descartes also discusses the structure of the eye, focusing on the optic nerves in the third Discourse, and explains the structure and use of the nerves in the fourth Discourse dealing with senses. In Discourse IV, he shows how critical he can be towards 'anatomists and physicians' who have not explained the use of the nerves. We must note, in this context, both the citing of William Harvey's name (Harvaeus) and of the title of Harvey's book (*De Motu Cordis*) in the margins of the *Discours*,[5] as well as the appraisal given in the text of 'an English physician, who must be praised for having broken the ice' on the circulation of the blood. Harvey is indeed the only author's name quoted in the *Discours*;[6] and his name is quoted respectfully, as that of someone having made a genuine discovery.

In order to understand properly Descartes' attitude towards Harvey, and Descartes' aim in medicine, we must take into account the medical context of the seventeenth century. It means that we – as readers at the beginning of the twenty-first century, accustomed to the use of the microscope, and of various recording devices dealing with the human body, the heart, its movements, and the circulation of the blood – must forget nearly all that we have been taught on this subject. Such an attitude is all the more difficult to adopt for modern physicians, who must forget their practice of X-rays, echographies, and NMR. It is also worth noting that in the seventeenth century, the anatomy of the heart and of the vessels was described otherwise than it is today, and as a result the terminology used by Harvey and Descartes is different from the vocabulary we are now used to.[7] Further, medicine had strong links with philosophy, as can be seen from the example of the famous School of Padua, where Harvey went to study medicine.

If we take into account the medical context of the first half of the seventeenth century, we must mention first that the choice of the heart as a subject of study is significant. The heart, the 'principal' organ since Aristotle, vied for the role of mediator between the soul and the body with the brain or part of the brain. The heart was indeed a theme of traditional importance in medical treatises. Anatomists who studied the heart insisted that it was very difficult 'to describe its admirable composition and structure', but by doing so one gains access to 'marvellous secrets of Nature' (*Naturae arcana*).[8] The choice of an explanation of the movement of the heart is the second point to comment on. To begin with, in trying to explain this motion, which is so difficult to observe, one arrives, so to speak, at the heart of physiology. Fernel, who coined this term, claimed that it is a matter of reasoning, because physiology deals with what can only be known thanks to reasoning, and not to the external senses. Then, according to Laurentius, 'the nature and cause of its perpetual movement is entangled with so many layers of difficulties and such great ones, that the learned Fracastorius thought that it was known only to Nature and to God alone'[9]. And in the first chapter of his 1628 treatise, demonstrating the movement of the heart and the blood, Harvey refers to Fracastoro to show both how complex the question is – and how daring his own explanation. Harvey also quotes Laurentius: 'I did not wonder at that which Andreas Laurentius had written, that the motion of the heart was like the ebbing and flowing of Euripus to Aristotle.' This first reference to Aristotle in Harvey's book alludes to Aristotle's exile in Chalcidia, where he could not discover the cause of the motion of the narrow strait of Euripus, 'which ebbs and flows at set intervals seven times by day and night'. Laurentius also mentions that 'Aristotle was so stricken with grief' that he died. The difficult question of the movement of the heart demonstrates how much philosophical themes and medical research were entangled in the seventeenth century, because the subject brought many important questions in its wake: the link between soul and body, the possibility of explaining Nature and discovering its secrets, and the status of Nature.

The question of the movement of the heart also leads to a study of a very important period in the history of medicine, because writing about the movement of the heart in 1637, as Descartes did, was to align oneself on one or other side of the debate generated by Harvey's *Exercitatio de Motu Cordis et Sanguinis in Animalibus,* which was published less than ten years earlier. Moreover, claiming, as Descartes does, that the movement of the heart is 'the first and most widespread',[10] that is to say, that this movement is the one to which others are subordinated, was indeed a daring claim at a time when the discovery of the circulation of the blood was proceeding to demolish the traditional divisions of the body to be found in anatomical treatises. It should in fact be remembered that the prevailing view before Harvey, derived from Galen, associated the liver with the veins and the '*pneuma phusikon*' (to become the *spiritus naturalis* 'natural spirits'), the heart with the arteries and the '*pneuma zotikon*' (to become the *spiritus vitalis* 'vital spirits'), and the brain with the nerves and the '*pneuma psuxikon*' (to become the *spiritus animalis* 'animal spirits'). And, in fact, what is at stake in these pages of the fifth part of the *Discours* (which are not merely quoting the passages dealing with man in the unpublished *L'Homme*) is an essential aspect of the resurgence of medicine and physiology in the first half of the seventeenth century.

Descartes makes a major breakthrough in physiology by rejecting the interpretation which worked in terms of faculties previously used to characterise the functions of the body (the vegetative faculty dealing with the liver, the vital faculty dealing with the heart, and the animal faculty – in which 'animal' means relating to *anima*, i.e. soul – dealing with the brain). Descartes' major breakthrough is also associated with Harvey's discovery of the circulation of the blood and with a Cartesian mechanical explanation of the heat of the heart (rather than the traditional 'innate heat'), understood as the principle of life.[11] In dissociating the heart from the soul, and rejecting any connection between the heart and the sun, at the very time that Harvey was making use of the metaphor of the heart as a microcosmic sun (the heart in the microcosm being like the sun in the macrocosm), Descartes demonstrates how remarkable his conceptions are. Moreover, Descartes defends a thesis about the cause of the movement of the heart that differs from the one given by Harvey in the first part of his book published at Frankfurt am Main in 1628. Since Descartes accepts with Harvey's discovery of the circular movement of the blood, he retains the second part of Harvey's book, dealing with the demonstration of the circular motion of the blood in living animals. He focuses his attention on some points of Harvey's discovery of the circulation of the blood. As I shall show, Descartes' approbation is in fact a rewriting of this discovery, because Descartes conveys Harvey's discovery in a different context from the one in which it was first presented. Descartes' assumption of a mechanistic context, linked to the definition of a new anthropology, will obliterate Harvey's own Aristotelian and vitalistic context.

When Descartes mentions the 'perpetual circulation' of the blood in the body, he refers to 'an English physician' and quotes his name in Latin, Hervaeus, and the title of his book, *De Motu Cordis*, in the margin of the *Discours*. In this book written in French, rather than Latin, Descartes spreads Harvey's discovery among a new reading public – and not only among the learned.

The laudatory approval given by Descartes to the genuine novelty of Harvey's 1628 demonstration of the circulation of the blood, which can also be found in his correspondence,[12] in the *Passions de l'Âme*,[13] and in the *Description du Corps Humain*,[14] is all the more interesting since Descartes is usually reluctant to mention his sources. It is also worth noting because the recognition of the Harveian thesis of the circulation of the blood took a long time and provoked many objections, especially in France. The most famous of these, *Le Malade Imaginaire,* a play written in 1673 – that is, 36 years after the publication of the *Discours,* 45 years after the publication of the *De Motu Cordis et Sanguinis* – shows the young Diafoirus, Thomas, proud of offering his medical thesis against the '*circulateurs*' (the name given to the followers of Harvey) to Angélique. If Thomas Diafoirus behaves like a rather ridiculous lover, he does not behave like an old-fashioned physician: the play was written the year after King Louis XIV decided to have the circulation of the blood taught in Paris, in his gardens (in those days *Le jardin du Roi,* now *Le jardin des plantes*), by Dionis, a surgeon. In seventeenth-century France, Faculties of Medicine were very conservative, even at Montpellier, as can be seen from John Locke's *Journal.* When Locke (both philosopher and physician) travelled in France in 1676, he reported in his *Journal,* on Wednesday 18 March, on 'the manner of making a doctor' at the University of Montpellier, giving his low opinion of the orations and writing that the Chancellor's oratory was directed 'against innovation'.

Descartes' publicising and supporting Harvey's discovery of the circulation of the blood, and debating with Harvey on the cause of the motion of the blood, is all the more striking because Descartes was not a doctor of medicine and had never attempted to get a degree in medicine. Harvey was a fully qualified medical doctor, having studied at Cambridge and above all at Padua, the famous university that offered medical students a good training both in theory and in practice; this was exceptional in those years when medical training was characterised by the variations in length of the studies according to the university, the poor quality of teaching and the inadequate use of human dissection. And although Harvey was not, at the time of publication of the *Discours,* considered to be the founder of modern physiology, he was nevertheless important both as a physician and as a lecturer. From 1609 onwards he had been a physician appointed to St. Bartholomew's Hospital, London; from 1616 he had held the important post of Lumleian lecturer to the College of Physicians of London, and it was here that he first alluded to his discovery.[15] In 1618 Harvey had also been appointed physician to the King (Medicus Regis juratus, 'sworn physician to the King').

As for Descartes, it is worth noting that from the moment when, at the end of 1629,[16] he became interested in medicine, he read many books and performed many experiments. This point is very important – not only because we should reject the idea of Descartes as a mere 'amateur' in medicine,[17] but also to remind ourselves of the letters that fully qualified physicians wrote to Descartes about medical problems,[18] and to recollect that Harvey himself discussed Descartes' ideas on the movement of the heart in his second *Reply to Riolan the Younger.*[19]

Descartes, Harvey, and medicine: 'Vesalius and the others'

From Amsterdam, where he was performing dissections, Descartes wrote to Mersenne, on 15 April 1630: 'I am now studying chemistry and anatomy simultaneously; every day I learn something that I cannot find in any book.'[20] Descartes did not say anything about the books he was reading. But, on 20 February 1639, writing about the readings and the anatomical experiments he had been dealing with for 'eleven years' (which means from 1629, because Descartes used to count including both the initial and final year), Descartes said: 'In fact, I have taken into consideration not only what Vesalius and the others write about anatomy, but also many details unmentioned by them, which I have observed myself while dissecting various animals.'[21]

From this quotation, it is clear that Descartes acknowledges a debt towards Vesalius, and towards the 'others', for his knowledge of anatomy. This point should be taken seriously, because examining this reference to 'Vesalius and the others', and observing that in this quotation Descartes is promoting medical experiment, leads us to consider Descartes in a continuous line in the development of anatomy from Vesalius onwards. The coherence of the Cartesian sources in science should be noted, because Descartes, in medicine as in physics, in *L'Homme* as well as in *Le Monde*, wanted to draw information from the most recent sources: from Copernicus to Galileo in physics, from Vesalius to Bauhin and Harvey in medicine.

Let us turn to medicine. In the remarkable year 1543, Copernicus published his *De Revolutionibus Orbium Coelestium* in Nuremberg, and Vesalius, from Brussels, had his *De Humani Corporis Fabrica Libri Septem* published. At that time Vesalius was teaching anatomy at Padua, 'the most famous school in the universe', as he wrote in the Preface of his treatise.[22] It was in Padua, when he was not yet thirty, that Vesalius had written the final version of his treatise in seven books on the fabric of the human body, before sending it for publication at Oporinus, in Basel. Vesalius' aim in his treatise is to show the 'fabric of the human body' and to reverse the decline of anatomy. The preface of the treatise denounces the 'loss' of anatomy, and contains information about Vesalius' medical studies. Vesalius argues against the bookish teaching he received in Paris and wants to restore the 'lost knowledge of the human body'.[23] He also writes about his conception of man. He mentions the 'charm' of studying the organism which is 'the most perfect among all the creatures', and of examining with attention what is 'the refuge and the instrument of our immortal soul, that the Ancients, thanks to the remarkable correspondence with the world, had rightly named microcosm (*microcosmus*)'. These ideas, one dealing with the perfection of the human being that is shown in Vesalius' book, the other associated with the definition of man as a microcosm and with the theme of Nature creating this noteworthy, remarkable work of art, will be of great importance in medical treatises after Vesalius, even in Harvey's treatise on the movement of the heart and the blood, as we shall see below. In 1555, Vesalius published a revised edition of the *Fabrica,* in which he showed himself more concerned with embryology and vivisection.

When Descartes mentions the name of Vesalius in his correspondence, he also refers to the 'others' – Vesalius opened the way, and other anatomists had followed his example. Such was the case in the Low Countries, where in the first third of the seventeenth century there was a revival of interest in Vesalius, as can be shown from the editions directly inspired by him. In 1633 a new edition of Vesalius' *Epitome Anatomica* was published in Amsterdam, with commentaries by P. Paaw. The full title of this small book, first published in Leyden in 1616, is *Andreae Vesalii Bruxellensis Epitome anatomica, Opus Redivivum.*[24] The anatomical aspect of medical life is also shown in Rembrandt's famous painting *The Anatomy of Dr Tulp* (Figure 15.1), painted in 1632 in Amsterdam, that is, in the city and at the moment when Descartes was preparing *L'Homme.*[25] This historical painting depicts the only public anatomical demonstration in Amsterdam in 1632, performed by Dr Tulp[26] on a condemned criminal, who had been hanged the day before the dissection began. This painting is also a group portrait (the members of the anatomical guild), and a painting belonging to the history of medicine and ideas, because what is shown is an anatomical demonstration beginning with the explanation of the *musculi digitos moventes* of the lower left arm and hand. This fact is important, because Renaissance anatomies began with the *venter inferior* (the lower belly), as can be seen from the title page of the *Fabrica* by Vesalius, published in 1543 and 1555 (Figure 15.2). In the seventeenth century, as in the sixteenth, no anatomy would begin with the arm, so Dr Tulp must have asked Rembrandt to portray him in this way. And if Tulp asked Rembrandt to show him dissecting the muscles of the forearm that allow the fingers to move, it was because Tulp wanted to be painted in a Vesalian light. Tulp wanted to be seen, to be acknowledged, as a 'new Vesalius', as 'The risen Vesalius', 'Vesalius redivivus'[27] – because Vesalius' large woodcut portrait, which is found at the beginning of the *Fabrica,* 1543 edition (Figure 15.3), and which was reprinted many times,[28] shows Vesalius dissecting a lower arm. Rembrandt's painting thus established a link between Vesalius and Tulp (Paaw's pupil), showing the Vesalian Renaissance in the Low Countries in 1632.

During this period, many books in Europe were printed in the Vesalian style. This allows us to make precise the Cartesian reference to 'the others', the other anatomists after Vesalius. In *Le Principe de Vie chez Descartes,* I argued that Caspar Bauhin, who taught medicine in Basel after having studied in Padua, was the most important among the 'other anatomists' Descartes was alluding to in his letter to Mersenne. In 1590 Bauhin published a treatise directly inspired by Vesalius, including the title *De Corporis Humani Fabrica.* In one of his other treatises, the most

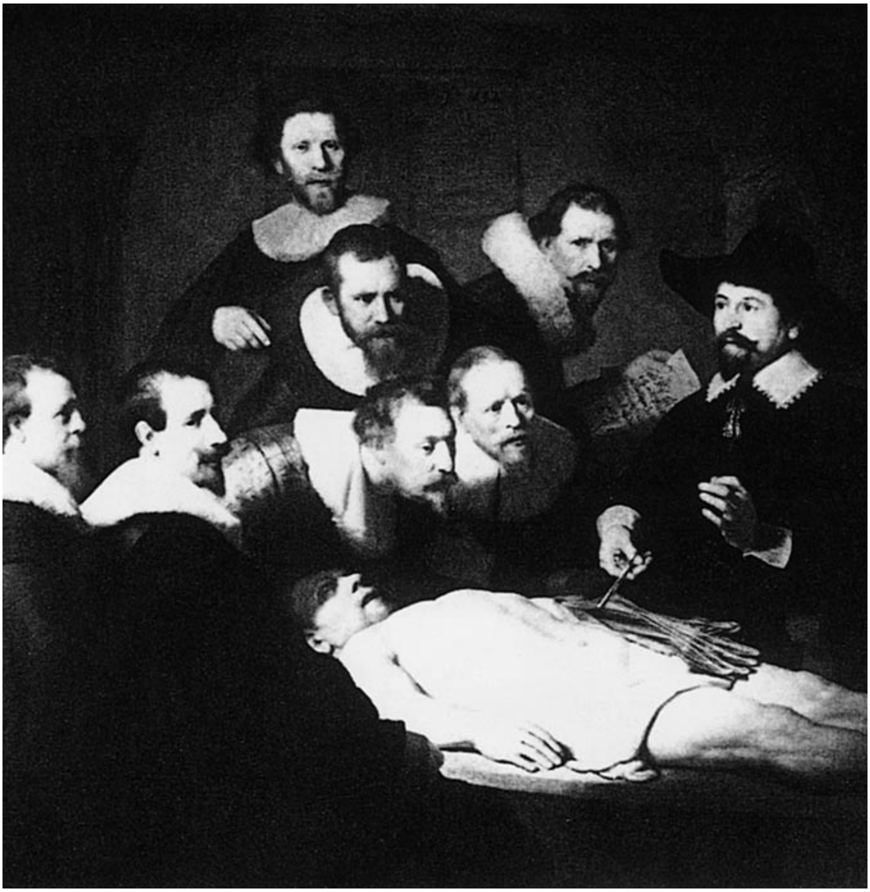


Figure 15.1 Rembrandt, *Anatomy Lesson of Dr. Tulp.*

famous, very well known in the Low Countries, Bauhin used the anatomical drawings found in Vesalius' books, and he entitled his treatise – published in Frankfurt in 1605, then reprinted and enlarged in 1620–21 – *Theatrum Anatomicum,* 'Anatomical Theatre'. These anatomical drawings helped Descartes from the moment he began to practice his anatomical experiments. In 1629, Descartes lived in Kalverstraat (Street of the Calves) and, ten years later, he reported to Mersenne: 'During one winter in Amsterdam, I used to go nearly every day to a butcher's, to see him slaughter animals, and to have brought to my house the parts of the animals I wanted to anatomise at leisure.'[29] During the winter of 1632, Descartes wrote to Mersenne:

> My discussion of man in *Le Monde* will be a little fuller than I had intended, for I have undertaken to explain all the main functions in man. I have already written of the vital functions, such as the digestion


ANDREAE VESALII
BRVXELLENSIS, SCHOLAE
medicorum Patauinæ professoris, de
Humani corporis fabrica
Libri septem.
CVM CAESAREAE
Maiest. Galliarum Regis, ac Senatus Veneti gratia & priuilegio, ut in diplomatis eorundem continetur.
BASILEAE.

Figure 15.2

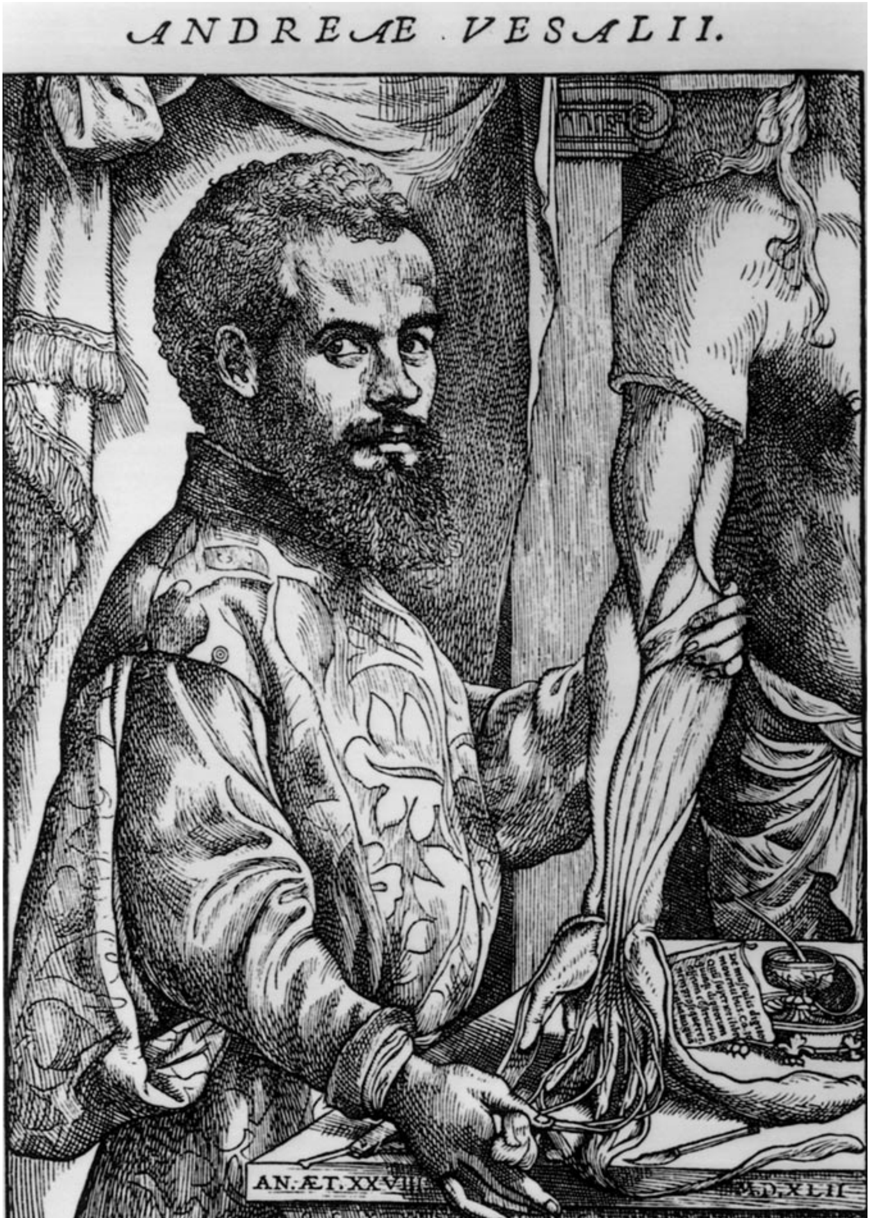


Figure 15.3

> of food, the heart beat, the distribution of nourishment, etc., and the five senses. I am now dissecting the heads of various animals, so that I can explain what imagination, memory, etc., consist in.[30]

In *L'Homme,* Descartes located the seat of imagination and common sense in a gland in the brain. In this treatise, Descartes did not mention the name of the gland – the name pineal gland or *conarium* is to be found in some letters in 1640[31] – but referred to it by using the letter 'H'. This apparently indicates that Descartes was referring to an anatomical plate dealing with the internal structure of the brain, found in Bauhin's treatise *Theatrum Anatomicum,* where the pineal gland or *conarion* is identified with the letter 'H' (Figure 15.4). In the *Excerpta Anatomica,* Descartes' notes about his anatomical experiments, he refers twice to Bauhin. Bauhin's *Theatrum Anatomicum* is indeed an important book when one is interested in Descartes' biology, and in my edition of *L'Homme,* I quoted the *Theatrum Anatomicum* to explain Descartes 'in context', and reproduced anatomical plates from the *Theatrum Anatomicum.* Bauhin was indeed a 'learned anatomist' whom Descartes wanted his readers to refer to in *L'Homme.*[32]

This anatomical theatre also recalled Bauhin's studies at Padua, where he was taught anatomy by Fabricius of Aquapendente, the founder of the famous permanent wooden anatomical theatre. Bauhin directly alluded to one of the dissections performed in Padua by Fabricius when, in book four of the 1605 edition, he refers to the public anatomical demonstration of the existence of the valves in the veins. At the end of the book, Bauhin gives, in a slightly different form, some of Fabricius' plates from the *De Venarum Ostiolis* (1603). So Bauhin updated Vesalius' plates – such is the case with the valves of the veins, a very important anatomical discovery, about which both Harvey and Descartes thought deeply (Figure 15.5). This plate will be shown in Harvey's *De Motu Cordis et Sanguinis,* together with Harvey's experiments on the ligated arm to demonstrate the circulation of the blood and explain the function of these valves (Figure 15.6).

Bauhin's *Theatrum Anatomicum* gave Descartes the opportunity to see in a smaller size than in Vesalius' books, very good anatomical plates, and read a less controversial text than the *Historia Anatomica* by Laurentius, where each chapter is followed by questions and controversies. If nowadays we have forgotten Bauhin's name, we should remember that Bauhin was quoted with praise by Harvey in his *De Motu Cordis,*[33] and that the *Theatrum Anatomicum* was the reference book when Harvey was giving his anatomical Lectures in London from 1616.[34]

Descartes' knowledge of anatomy comes from Vesalius and Bauhin, while his knowledge of embryology comes from Fabricius of Aquapendente, and from his own experiments, as can be seen from a letter to Mersenne, of 2 November 1646.[35]

When Descartes refers to Fabricius, he once more acknowledges his

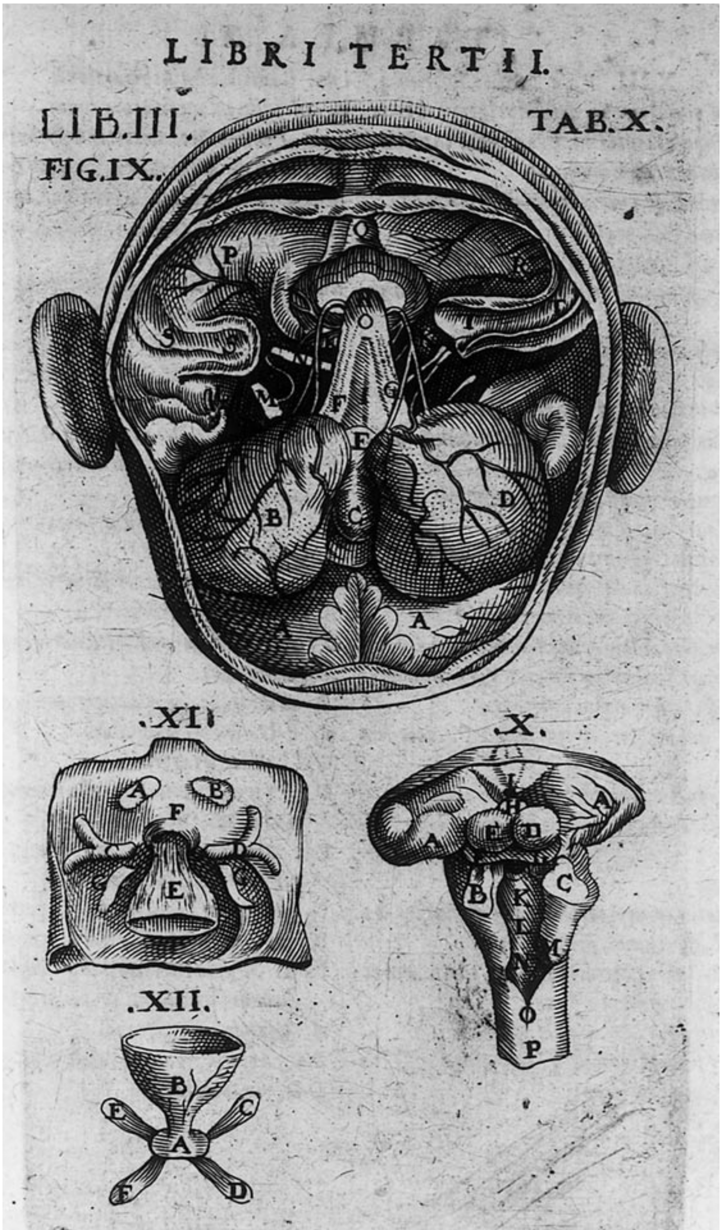
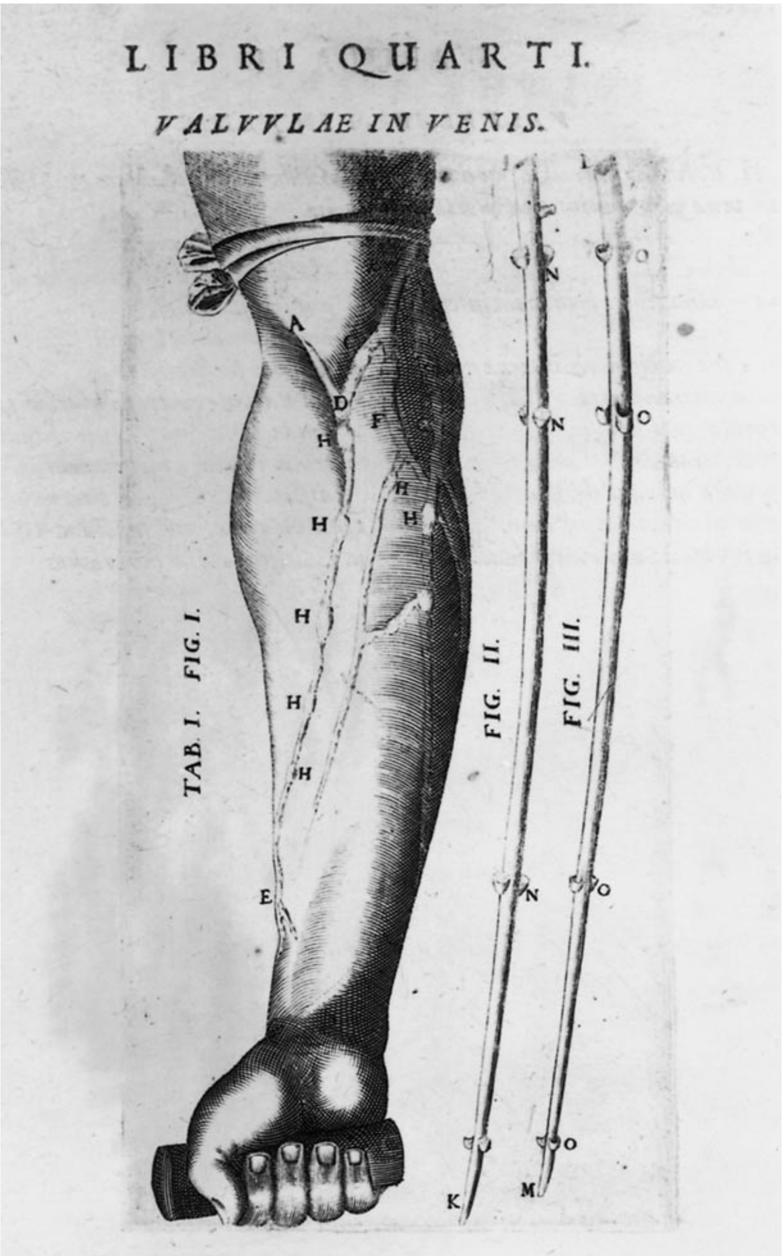


Figure 15.4


LIBRI QUARTI.
VALVVLAE IN VENIS.
TAB. I. FIG. I.
FIG. II.
FIG. III.
A
D
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E
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Figure 15.5

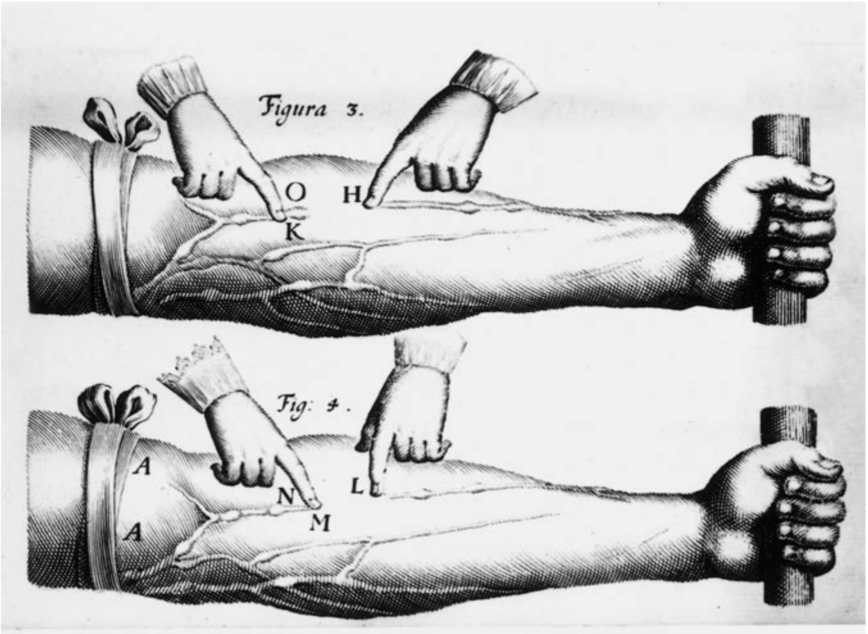

Figure 15.6

debt to Renaissance medicine. Descartes read the two embryological treatises of Fabricius, *De Ovi Pulli* (The Formation of the Egg and Chick) and *De Formato Fœtu* (The Formed Foetus), very carefully.[36] These books have magnificent engraved plates showing the formation of the chick, the formation of the human foetus, the formation of the foetus of the sheep, the cow and the horse, plates which helped Descartes in his practice of embryological dissections. In these experiments, Descartes was interested in the order in which the organs form during development or gestation. But he also owes to his reading of the *De Motu Cordis et Sanguinis* his considerations on the heart in the embryo representing the beginning of life.[37]

When quoting the embryological treatises of Fabricius, Descartes was referring to a very famous teacher of anatomy at Padua. Fabricius had taught anatomy and surgery at Padua for half a century. When Harvey went to Padua, Fabricius was teaching anatomy and surgery, performing anatomical demonstrations and dissections. Fabricius had a great influence on Harvey. His ambitious programme of research was to prepare a *Totius Animalis Fabricae Theatrum*,[38] which he planned to illustrate with coloured life-size plates, each to be accompanied by an engraving in black and white. His first book was the *De Visione, Voce, Auditu* (On Sight, the Voice and the Ear), published in 1600, with plates. Then, in 1603, were published the *De Locutione et eius Instrumentis* (About Speech and its Instruments), and the *De Venarum Ostiolis* (the famous treatise on the Valves in the Veins), and *De Brutorum Loquela* (On the Speech of Animals). Then came the embryological treatises and the *De Respiratione et eius Instrumentis* in 1615, and later on the new edition of the surgical works (*Opera Chirurgica*).

A study of Descartes' medical sources – Vesalius, Bauhin and Fabricius – leads us to note two important points. The first is that Descartes' readings in medicine were far from the *Parva Naturalia* of the scholastics and from Fernel's treatises (sources that Gilson gave too great an importance in his famous paper 'Descartes, Harvey et la scolastique').[39] The second is that Descartes' acknowledged sources – Vesalius, Bauhin, and Fabricius – sources that are genuine, as can be seen from reading Descartes' medical writings, are the same as Harvey's reference books in anatomy and embryology. And, of course, Descartes also refers to Harvey himself in his writings. This agreement on reference books and on the importance of experiments is all the more fascinating when we note that Descartes had studied medicine by himself.

Descartes' medical study of the nature of man and his reading of Harvey's *De Motu Cordis et Sanguinis*

The Cartesian challenge was all the more important as Descartes had studied the medical tradition in carrying out his ambitious research programme dealing with 'the nature of man',[40] to which he had devoted himself from June 1632. When referring to 'the nature of man' – in a letter to Mersenne explaining how fundamental this study became in *Le Monde,* and later in quoting this expression in the Sixth Meditation, the *Principia,* and the *Passions de l'Âme* – Descartes is making use of a phrase that had become popular in medical texts. The reason for this was that 'The Nature of Man' was the title of one of the works assigned to Hippocrates, then commented upon by Galen, and usually quoted in medical and anatomical treatises of the Renaissance and the seventeenth century. This treatise, which sets out a theory of physical human nature, was nonetheless mentioned in a context where man fits into the macrocosm.

This question, dealing with the nature of man as linked with the status of Nature, is studied in these medical treatises and is alluded to in Harvey's book on the movement of the heart and the blood. And I think that it is in the context of this question that we can clearly understand the new way in which Descartes wrote about medicine. The pages Descartes devoted to medicine in the *Discours* and in the *Dioptrique* show that Descartes separated philosophical themes or metaphysical problems (such as the role played by the Creator or by God, the status of Nature, of the soul) from the medical question of the study of the body, in which the investigation about the movement of the heart is a pre-eminent example.

These questions are linked with the Descartes–Harvey debate on the movement of the heart, as can be seen from study of the controversy. Coming to the nub of the controversy between Descartes and Harvey, we find that its study reveals several important aspects of the Cartesian conception of physiological problems. The first is the rejection of the macrocosm–microcosm comparison, a rejection grounded on Cartesian physics (the *Discours* was written after *Le Monde*, which contains *L'Homme*), and evidenced by the fact that Descartes says nothing either about the heart–sun metaphor, or about the microcosmic analogy, while Harvey not only quotes these analogies, but also makes use of them at important places in his book.

From *Le Monde* and *L'Homme* on, Descartes invoked the 'laws of Nature'. If this expression can be found in medical treatises, for instance in Du Laurens' *Historia Anatomica,* it means regular and prefixed movements, certain and well-determined laws, but something unknown to human beings.[41] In contrast, the laws of Nature in Descartes' new system of the world are the laws of motion explained in *Le Monde* and derived from the immutability of God. And the body about which Descartes writes in *L'Homme* and Part V of the *Discours,* like the material world in general, is ruled by the laws of Nature 'established' by God,[42] and by the circulatory pattern that is shown in the world,[43] as in man with the circulation of the 'animal spirits' – i.e. the most subtle particles of blood – which is like the circulation of the blood. Descartes' embryology is also like a 'sort of living whirlpool'.[44] It is obvious then that for Descartes, the link between the world and man is totally different from the descriptions of the similarities between macrocosm and microcosm that were very common in medical treatises. In his Preface to the *Fabrica,* Vesalius asserted that 'the Ancients' named man 'microcosm (*microcosmus*)' because of all the close connections with the world. This theme of man as a microcosm can be found in most of the medical treatises of the seventeenth century and is associated with the parallel between the sun and the heart that was a widespread theme in the Renaissance, not to mention in Agrippa's *De Occulta Philosophia.*[45] These themes can also be found in the works of Robert Fludd,[46] and Descartes would have read them in the writings of Fernel,[47] Kepler,[48] and Harvey. The parallel between the sun, necessary for all life, and the heart, 'principal' organ in the body, was indeed very common in medical books, and was also linked with the Paracelsian influence on medicine, as can be seen from Fludd's writings, and from the influence of astrology in medicine. Physicians who wrote about the parallel between the sun and the heart generally called upon 'the Ancients', as can be seen from Laurentius,[49] and maintained the traditional geocentric universe, even Fludd, whose system of the world was centred around the sun, and who rejected the work of Copernicus. When explaining that the heart is the principle of heat and life, Anatomists also frequently called the heat in the heart 'divine'.[50] If Descartes does not retain this link between the sun and the heart, it is because he rejects the explanation that underlies such a connection, namely that the principle of life originated from the heavens, or that such a link between the sun and the heart lends support for a cosmology derived from the Greek legacy. Descartes rejects these ideas connected with a tradition Harvey is not opposed to. We must not lose sight of the fact that in Harvey's use of the metaphor of the heart being like the sun, there is no influence of Copernicus or Galileo. Harvey, when in Padua, attended Fabricius' lectures and anatomical demonstrations, but there is no evidence that Harvey attended Galileo's lectures. Though it has been suggested that in Padua he was influenced by Galileo's teaching in astronomy,[51] it should be remembered that while Harvey was a student in Padua, Galileo was not teaching the Copernician system, but the works of Euclid and the *Book of the Spheres.* It was Descartes who followed the theses of the 'new astronomers' – Copernicus and Galileo in *Le Monde*; the condemnation of Galileo's *Dialogue on the Two Chief World Systems* by the Congregation of Cardinals, established to censor books, resulted in his not publishing a book with 'the proscribed movement'[52].

If Descartes did not agree with Harvey on the question of the cause of the movement of the heart, it is because his own chronology of the phases of the cardiac cycle is in accordance with the explanation of the origin of heat conceived as the principle of life. If the expulsion of blood occurs during systole, namely during the phase of contraction of the heart and thereby during its diminution in volume (as Harvey says[53]), there must be something in the heart that is the cause of its contraction. In his *Description du Corps Humain* (published in 1664 with *L'Homme*), Descartes explained: 'Now if we suppose that the heart moves in the way Harvey describes, we must imagine some faculty which causes this movement; yet the nature of this faculty is much harder to conceive of than whatever Harvey purports to explain by invoking it.'[54]

Descartes wished to avoid calling upon a '*vis pulsifica*' in the heart,[55] or, as Harvey did, upon the expansive and contractive action of the heart itself, which cannot be accounted for. So Descartes explained the expulsion of the blood from the ventricles as a kind of natural phenomenon occurring in the blood itself, a process like ebullition, or fermentation, the result of the production of heat taking place in the heart. Therefore the expulsion of the blood must coincide with the expansion and not with the contraction of the heart, and this is explained in the *Discourse,* as well as in the *Description.*[56]

When Harvey describes blood 'that is warmer, perfected, vaporous, full of spirit, and so to speak, alimentative',[57] and the heart 'as a fountain or inmost shrine or the body', his ideas on the blood and on the heart are directly derived from Aristotle's writings; this is paradoxical given the importance of Harvey's discovery in the history of medicine, and it explains why the first recognition of Harvey's discovery in print came from Robert Fludd's *Medicina Catholica* of 1629. Fludd was a mystic physician who called Harvey 'his friend, collegue and compatriot well versed not only in anatomy but also the deepest mysteries of philosophy'.[58]

So it can be said that Descartes gives the Harveian theses a shift of emphasis, because Descartes separates the experimental proofs given by the English physician from the philosophical background on which Harvey was still dependent. The treatise on the movement of the heart and the blood illustrates that its author was indeed a brilliant and an inspired experimenter, but the book also reveals a physician dependent on the philosophical tradition that was taught to medical students at Padua. Descartes, on the other hand, questioned the conceptual framework in which Harvey fitted his brilliant discovery.

If the *Discours* accepts the circulation of the blood, it should be noted that Descartes only quotes with approval the Harveian experimental proofs, and that he does not mention the Aristotelian reference that gave birth, according to Harvey himself in ch. 8 of *De Motu Cordis et Sanguinis,* to the definition of the circular movement of the blood in animals. When Harvey writes that 'we may call this motion circular in the same way in which Aristotle says that the air and the rain imitate the circular motion of the heavens', this is not merely rhetorical. Harvey believes in the analogies between the world as cosmos and man. Harvey, indeed, accepts one of the major principles of Aristotelian cosmology, which Descartes rejects – that phenomena in the sublunary world are seen as imitations of the celestial pattern. As W. Pagel writes, 'circular motion serves the preservation and maintenance of both these worlds'.[59] By referring to Aristotle in order to define the circular motion of the blood, Harvey shows the importance of his studies in Padua through the deep influence on him of the Aristotelian philosophy taught by Cremonini, who in 1590 filled the vacant chair of the famous Paduan Aristotelian philosopher Giacomo Zabarella. The persisting Aristotelian influence in Harvey's writings can also be seen in his *De Generatione Animalium,* published in 1651, where Harvey himself acknowledges several times his debt to both Aristotle and Fabricius.

It therefore becomes clear that the presentation of Harveian views in the *Discours* is accompanied by a shift of emphasis, Descartes revealing (except on systole) a much more 'modern' Harvey than the one that can be found by reading the treatise of 1628. This judgement is confirmed by Descartes' emphasis in the Harveian demonstration on the assumption of the existence of 'many small passages' (the anastomosis) at the extremities between the arteries and the veins, that Harvey himself – who was writing as was Descartes, before the invention of the microscope – was unable to see. This example illustrates the Cartesian method of explaining the visible actions of visible organs in terms of the invisible actions of structures too small to be seen *at that time.* Here Descartes is anticipating the use of magnifying lenses in the advancement of biological knowledge and expects many benefits from it, as can be seen from the *Dioptrique,* Discourse 10.

Descartes follows Harvey in asking 'anyone unversed in anatomy to take the trouble . . . to have the heart of some large animal with lungs dissected before him'.[60] Harvey indeed insisted on these precise observations. But Descartes, in describing the structure of the heart, parts from Harvey when, considering the cardiac valves ('the eleven little membranes'), he writes 'there is no need to seek any reason for the number of these membranes . . . beyond' mechanical reasons due to their structure and their distribution in the heart.[61] Thus Descartes discards the respectful attitude towards the skill of Nature that can still be found in Harvey's treatise.[62] In ch. 8 of *De Motu Cordis*, for instance, Harvey expresses his admiration in considering the 'carefully balanced and exquisite contrivance of the valves and fibres and from the rest of the fabric of the heart'. Harvey is here following ideas expressed by, for example, Bauhin and Laurentius and grounded in Vesalius' famous treatise, *De Humani Corporis Fabrica Libri Septem*. Such is the case with the part played by 'Nature' and by admiration. It should be noted that in Vesalius' title the word *'fabrica'* does not stand for the word 'structure', as it is generally translated,[63] and does not just mean the study of the human body that stands on the bony structure of the body that is shown, in the first book, by the famous skeletons miming animation or meditation. The word *'fabrica'*, preferred in the title to the word *'structura'*, which appears in the treatise,[64] deals with a conception of the body as a remarkable piece of work[65] made by an *'Opifex'*[66] or by Nature (*Natura*)[67], which is frequently associated with Providence.[68] The word *'Opifex'*, too, means the remarkable piece of work made by the Creator, who, for instance, thanks to his 'ingenuity' (*industria*),[69] has associated muscles and nerves. In this respect Vesalius is inspired by the praises that Galen gave to the Creator.[70] But the illustrations in Vesalius' treatise emphasise the aspect of the human body as a masterpiece, a genuine work of art.[71] When publishing his treatise about the valves in the veins (*De Venarum Ostiolis*), Fabricius explained that the eight anatomical plates illustrating his discovery prove '*admirabilem naturae industriam*' (the wonderful work of nature). Bauhin echoed this in his *Theatrum Anatomicum*, and Harvey writes about the 'skill' of Nature.[72]

Compared to this medical tradition, Descartes' assertions about nature, as well as his explanations of the functions of the bodies, are original. Descartes tells us that 'by nature I do not mean some goddess or any other sort of imaginary power . . . but matter itself'.[73] In order to explain the organic functions of the human body Descartes refers to mechanical models instead of praising Nature or the 'skill of Nature'. These mechanical models are found in Descartes' writings from *L'Homme* onwards in order to explain physiological functions. They are often derived from Descartes' reading,[74] but used in a different context, that of the Cartesian systematisation of mechanism. The *Discours* refers to the unpublished treatise of *Le Monde* including *L'Homme,* uses the term 'automaton' and makes public the hypothesis of 'animal-machines', with the comparison of a 'clock consisting only of wheels and springs' that measures time 'more accurately than we can with all our wisdom'.[75]

These mechanical comparisons as explanations of physiological functions common to both humans and 'animals lacking reason' are also original because they are linked with the Cartesian use of the expression 'there is no wonder (*ce n'est pas merveille*)', for instance in *L'Homme,* in the *Description,* and in his correspondence.[76] The reason is that Descartes considered medicine as a scientific explanation not requiring the traditional praises to the human body, leading to praise of God or the Creator, or creating the devotional atmosphere of medical treatises of the Renaissance and of the first half of the seventeenth century.

Looking more closely at the account of Harvey's discovery in the fifth part of Descartes' *Discours* leads the reader to realise that Descartes intends to reject some important theses of the medical tradition, including those regarding Nature and its teleological assumptions, assumptions that Harvey still makes in his treatise. We shall return to this point below. What the Harvey–Descartes controversy shows above all, however, is that the Cartesian explanation of the motion of the heart does not reduce to trying merely to give a coherent description of vascular phenomena, a task that Harvey, the specialist, performed so brilliantly. Descartes is not such a specialist, and has wider issues and a greater challenge to face. In Descartes' project, *L'Homme* is a part of *Le Monde,* and in the *Discours,* where the unpublished treatise is alluded to, Descartes chooses the motion of the heart as a model for the explanation of all the movements in the body. Such an attempt is a challenge to traditional medical theories linked to a cosmology derived from the Greek legacy, and opens the way to a new physiology rejecting both the traditional interpretations in terms of 'faculties' derived from the Galenic tradition, and the Aristotelian legacy in medicine that was so important in medical writings, and that Harvey's work bears witness to.

The Harvey–Descartes debate on the cause of the motion of the heart is also significant because of the contrast of two personalities with different backgrounds, and different purposes in publishing their ideas. Harvey was a doctor of medicine, but Descartes' work, although published anomymously, reveals its author at once as a polymath who had written a 'Discourse on the method of directing one's reason and seeking truth in the sciences'.

In this *Discours,* Descartes explicitly raised the question about man in a medical context, while going against medical tradition. This is the case when Descartes presents an explanation of biological functions derived 'only from the disposition of their organs',[77] from the *Discours* to the *Passions* and the *Description.* To explain the disjunction between the soul and vital phenomena which features in Cartesian mechanistic biology, the *Discours* asserts, summarising *L'Homme*: 'So I contented myself with supposing that God formed the body of a man exactly like our own ... without placing, in the beginning, any rational soul or any other thing to serve as a vegetative or sensitive soul'.[78] In such a body, without any Aristotelian or scholastic souls, Descartes places the famous 'fire without light'. This life principle, defined as the heat of the heart, excludes any vitalism (long before the term existed), because this is a fire whose nature is in no way different 'from that of the fire which heats hay when it has been stored before it is dry, or which causes new wine to seethe when it is left to ferment from the crushed grapes'.[79] This fermentation model, reduced to 'mere motion', is important in Descartes' biology both to explain the heat in the heart and the formation of the various organs in embryology.

The elimination of the non-intellectual functions of the soul, together with the rejection of the definition of man as a microcosm (still the prevailing view[80]) constitutes the philosophical motif of Cartesian physiology, from *L'Homme* to the *Passions*, not to mention the *Discours* and the Sixth Meditation.

Descartes' new anthropology

It can be said without anachronism that Descartes defines a new 'anthropology', for this notion can be found in 1618 in the *Anthropographia* of Riolan the Younger (translated into French in 1629), and it is the first word of the *proema* in the anatomy treatises of Caspar Bartholin the elder in 1632, and his son Thomas in 1677;[81] Dionis also makes use of this notion.[82] The originality of Descartes' anthropological ideas results from his assertion of the singularity of the rational soul, or a human mind 'better known than the body',[83] whose union with the body defines a 'real man',[84] and also from his assertion of a body that functions thanks to the 'disposition of the organs', and which is given life by the heat in the heart. As the soul is no longer either a principle of life or a principle of movement, and as death 'never occurs through the absence of the soul',[85] the body, though it is not 'our better part',[86] becomes for Descartes a major subject of investigation.

The body, about which Descartes writes in *L'Homme* and the fifth part of the *Discours,* is ruled by 'the laws of mechanics, which are identical with the laws of nature'.[87] These Cartesian texts, which offer a new definition of nature, also propose a new relation between man and nature, in which the study of the 'eyes of the onlookers (*les yeux des regardants*)'[88] is very important. Descartes' deep interest in the physiology of vision and his strikingly novel way of dealing with its problems, already considered in *L'Homme,* appear in the sixth Discourse of the *Dioptrique,* which deals with vision in an original and extensive way in order to define a fundamental aspect of the relation between man and the world.

The *Dioptrique* was the first book Descartes wanted to publish after he decided not to have *Le Monde* published because of Galileo's condemnation. This text, published in 1637, is of paramount importance in Descartes' philosophy, because it establishes the Cartesian theory of knowledge by setting out a new explanation of both the bodily and the mental conditions of visual experience, namely that there is no resemblance between ideas and things. The fourth Discourse in the *Dioptrique,* on 'the senses in general', as well as the opening of *Le Monde,* later explained by the long account of eyesight in *L'Homme,* demonstrate that our sensible representation (our perception) is not like the object that stimulates it. This argument relies on anatomical arguments: witness the fact that, when explaining his theory of vision (*Dioptrique,* Discourses V and VI, and *L'Homme*), Descartes' originality lies in his emphasising the function of the nerves. Compared with other explanations of vision written in the period immediately preceding his own, the boldness of the Cartesian text, and the illustration of the eye and the point of insertion of the optic nerve, is again worth noting. Descartes' originality can be confirmed by looking at treatises published just before the *Dioptrique* and *L'Homme*; the *Historia Anatomica* of Laurentius, as well as the *Œuvres Anatomiques* of Jean Riolan the Younger, show how puzzled these physicians were when considering the optic nerves, their precise location, their point of origin, their connections and their precise function.[89] Moreover Descartes' contributions to the theory of vision are far more innovative than those of Kepler, who was his '*premier maître en optique*',[90] and from whom he borrowed his explanations of the crystalline humour[91] and the title of his *Essai* dealing with optics (*La Dioptrique*). Descartes' strong insistence on the function of the optic nerves in the explanation of the sense of sight, also stated in the *Principia* (IV, art. 195), is undoubtedly the new element that enables him to refute the Aristotelian theory of a resemblance between our sensory perception and the things that produce them.

So Descartes' anatomical and physiological research, particularly on the nerves, on the inner region of the brain, and on the heart, are definitely linked with his philosophy. These texts from the *Discours* and the *Dioptrique*, and their links with the unpublished treatise, prove both the coherence of the Cartesian project of rebuilding the system of the sciences, born of the famous dreams of November 1619, and the depth and scope of Cartesian thinking about medical questions. They illustrate Descartes' development from 18 December 1629, when he wrote to Mersenne that he was going to 'begin studying anatomy'.[92] This was a genuine beginning, for there is no hint that Descartes was interested in medicine before 1629. Moreover, I reject the idea that the famous dreams of 1619 could have given Descartes an inclination to become a physician, and that Rosicrucian doctrines could have influenced Descartes' medical ideas.[93]

Descartes, therefore, was indeed really interested in medicine, had read many books and performed many experiments. If he was wrong in his explanation of the movement of the heart, as was shown by Harvey in 1649 and confirmed by Richard Lower in 1669, Descartes supported Harvey's discovery of the circulation of the blood and put it into a new conceptual framework. Descartes placed Harvey's discovery of the circular motion of the blood in a mechanical context; this 'modern' Cartesian framework will emerge as the only one likely to make progress in medicine, and will replace Harvey's own Aristotelian and vitalistic ideas. Descartes also opened the way to new lines of investigation, as with his study of the nerves, in *L'Homme* and the *Dioptrique*.

In this way Descartes demonstrated his aim of systematising the field of medicine. This is apparent, for example, at the end of the fifth Discourse of the *Dioptrique,* where he gives mechanical explanations for the transmission of images through the human body, in order to explain birthmarks that 'excite so much the admiration of all the Learned (*Doctes*)'.[94] In this Discourse, dealing with 'the images that are formed on the back of the eye',[95] Descartes invokes a 'small gland' located in the middle of the concavities in the brain, where the 'common sense' is located. Here the *Dioptrique* is complementary to the *Discours,* in not naming this gland – although any reader familiar with controversies in cerebral anatomy can identify it from these two texts as the pineal gland or conarium. This example demonstrates that Descartes was willing to declare himself on complex and controversial topics in medical treatises, regarding to the possibility of locating within one single centre in the brain the mental faculties (the famous internal senses) of memory, imagination and reason. The expression used by Descartes at the very beginning of the *Discours* – 'some other difficulties pertaining to medicine'[96] – is to be understood in the context of these controversies, which relate to theological debates. The anatomical indications of brain structure alluded to in the *Discours*, and more precisely in the *Dioptrique*, illustrate Descartes' wish to clarify and explain some 'difficulties' in medicine. The same holds for the passage, at the end of the third Discourse of the *Dioptrique,* in which he rejects 'the peculiarities (. . .) with which anatomists usually thicken their books'.[97] This critical statement which appears after a remark about the 'six or seven muscles which are attached to the eye', suggests that Descartes has in mind the lack of agreement among his immediate predecessors and contemporaries as to the number of oculomotor muscles, the statements made about their evocative names, and, above all, the views about man, who contemplates the sky and has six eye muscles, whereas the beasts, which always look down, have a seventh one which keeps the eye from falling out of its orbit.[98]

The pages which Descartes devotes to medicine show what is at stake with the publication of the *Discourse* and the *Dioptrics.* The deliberations on man, based on a profound study and redistribution of topics already approached in the unpublished treatise, centre on the transformation of both the status of medical discourse and of the place occupied by physiology and medicine in the field of knowledge. Descartes' medical explanations, grounded in the laws of physics (which includes physiology), and the comparisons he draws in order to explain the motion of the heart, as well as the sense of sight, represent a new way of considering medical questions. Rejected from the traditional treatises is not only the idea of man as a microcosm, but also the conception of man as the 'end of all created things'.[99] Descartes rejects the search for final causes, as can be seen from his rewriting of Harvey's description of the valves of the heart, as we have already noticed, and from his reply to Gassendi, who raised objections to Descartes' rejection of final causes in physics in the Fourth Meditation. Gassendi clearly reintroduced the concept of finality when he wrote to Descartes that 'we know that certain great thinkers have been led by a study of anatomy not just to achieve a knowledge of God but also to sing thankful hymns to him for having organized all the parts and harmonized their functions in such a way as to deserve the highest praise for his care and providence'. Gassendi followed traditional medical discourse in admiring the 'superb' functioning of the valves in the heart and praising 'the ineffable Providence which has so appositely designed the valves for this function'.[100] In his reply, Descartes writes that 'we cannot guess from this what purpose God had in creating any given thing'. Descartes contrasts physics where 'such conjectures are futile' with ethics 'where we may often legitimately employ conjectures' and where 'it may admittedly be pious on occasion to try to guess what purpose God may have had in mind in his direction of the universe'.[101]

Reasoning thus, Descartes prescribes a totally new way of approaching the question of man in medicine. At the beginning of his study of anatomy, and later on in the *Description,* he quotes the ancient injunction '*gnôthi seauton* (Know thyself)',[102] which had a medical application from the sixteenth century onwards, in order to justify the study of the human body – but at the same time he rejects the interpretations that had been linked to it. This injunction is inseparable from a consideration of the place of man in the universe, as justified by the microcosm-macrocosm parallel, and its significance is revealed by the context in which it is quoted, either in the context of praising God, or in the moralising context of pointing out the certainty of the body's ending as dust. Knowledge about the body is characterised in Descartes' works by a mechanistic explanation of its functions, which justifies the use of the expression 'there is no wonder' and is evidence of the rejection of the devotional perspective of praise of the Creator in medicine. The latter, especially among Christian physicians, entails giving due praise to God, and entails the thesis that knowing oneself is knowing God, '*cognitio sui-cognitio Dei*'. The *Historia Anatomica* of Laurentius opens with a demonstration of 'the dignity of man, the excellence of anatomy', the affirmation that 'there is nothing accidental (fortuitous) in the structure of the body', and continues with chapters entitled 'How profitable anatomy is to the knowledge of man's self' and 'How profitable anatomy is to the knowledge of God'.[103] Caspar Bauhin also invokes the maxim 'Know thyself' in his *Theatrum Anatomicum.* His aim is to convince the reader both that it is noble to practice dissection, and that the body is as worthy of study as the soul.[104] The invocation of the Delphic precept with its double meaning – on the one hand, the praise due to God, who created such a wonder as the human body, and, on the other hand, the statement of man as a microcosm – is not inconsistent with Galen's works, or with the texts coming out of the Galenic tradition, which marvel at the admirable structure of the human body in order to reveal 'the wisdom, the power and the goodness of the Creator'.[105] These texts concur in the ontological dignity of man asserted in neo-Platonist humanism, and all these themes can be found in the works of Bauhin, which Descartes had read. In such a context, the dissociation that Descartes establishes between reasoning about medicine and teleological or theological considerations is clear, as can be shown from the study of the motion of the heart (already mentioned), and from the study of vision. Descartes' works contain no judgments about 'the excellence of the eyes' such as open the study of vision in the *Historia Anatomica* of Laurentius ('As sight is admirable in its action, so the organ of sight is beyond any wonder.'[106])

Descartes also rejects the other anatomical application of the Socratic maxim 'Know thyself', as it relates to the ephemeral nature of human life. The most notable illustration of this, in terms of a pessimism strongly impregnated with gruesome moralising, is to be found in the inscriptions on the banners held by the images of skeletons standing around the galleries of the famous anatomical theatre at Leiden(Figure 15.7), a university that was a centre of Calvinist ascetism.[107] During the first third of the seventeenth century, in both Protestant and Catholic countries, death in its most sordid aspects was omnipresent – and not only in medical treatises. One consequence of Cartesian dualism was to banish speculation about the mysteries of the separation of soul and body which was given such prominence, and to explain in terms of mechanics the extraordinary feats sometimes performed by parts of corpses, to which in those days sensitivity was commonly attributed (as shown in the *Discours*[108]).

The originality of Descartes' biological ideas is also seen in another consequence of the affirmation of dualism: specifically, the statement, in the fifth part of the *Discours*, of the difference between man and the beasts. In establishing this difference with respect to the rational soul and language, Descartes is once again attacking the medical tradition. In their search for what determines the peculiar dignity of man, physicians had disputed about human reason and the human hand, echoing Aristotle, and emphasising, after Galen, the function of the hand. Rembrandt's famous painting 'The Anatomy of Dr Tulp' (see Figure 15.1) reveals the importance attached to the human hand. If Tulp suggested that Rembrandt should portray him dissecting the muscles moving the fingers of the human hand, this was because the scene had to be associated with the exceptional significance of the hand in medical texts. These books refer to Aristotle directly by quoting the passage about the hand as '*organum organorum*' or, indirectly, via Galen and the many pages he devoted to the hand in the *De Usu Partium*,[109] in relation to Aristotle and finalism.

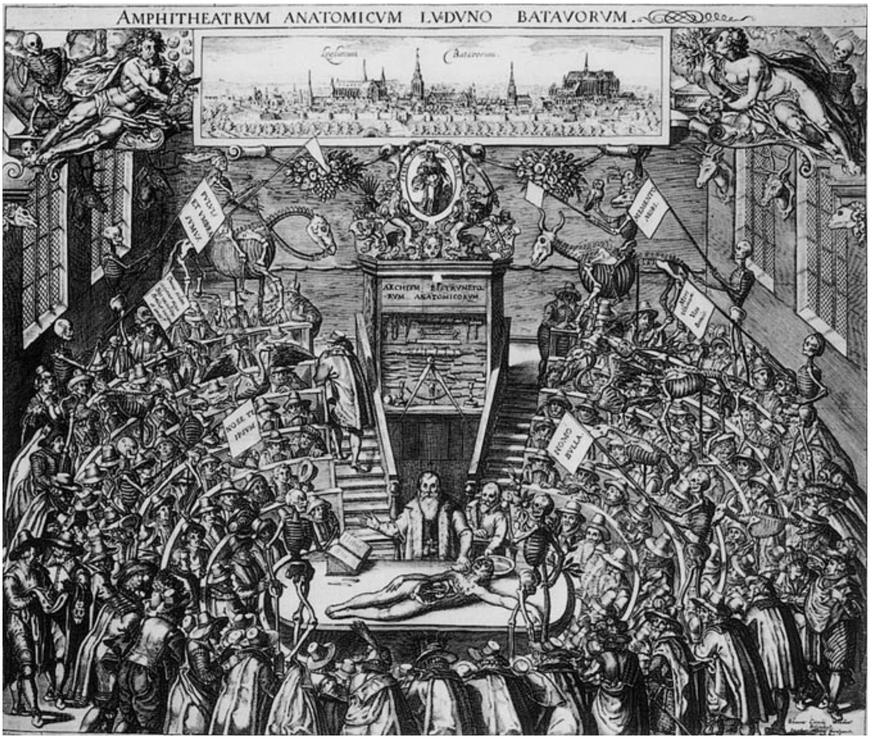

Figure 15.7 Engraving of anatomical demonstration, dated 1609, attrib. Dolendo, after a drawing by J.C. van't Woudt (Woudanus).

Descartes introduces further innovations with his analysis, in the Sixth Meditation, of the phantom-limb syndrome, which in no way affects the unity of the soul, and then with the description, in his *Principia* (Part IV, art. 196) of a young girl who complained of various pains in her fingers when bandages were placed on the arm from which the hand had been amputated. According to Descartes, this case proves that 'pain in the hand is felt by the soul not because it is present in the hand, but because it is present in the brain'. It also entails the rejection of the traditional '*qualitatem dolorificam*' (the so-called 'quality' of pain) that Fromondus put forward in objecting to Descartes' argument.[110] Extending the analysis of sensation given in the *Dioptrique* (Discourse IV), this example echoes the correspondence with Descartes on the *Discours* and the *Essais*.[111]

Descartes' influence in medicine: mechanism and the circulation of the blood

After the publication of the *Discourse* and the *Essais*, it was Cartesian anthropology, grounded in a mechanistic definition of life, that gave rise to reactions among the first readers. The objections of Fromondus and

Plempius in the autumn and winter of 1637–8 demonstrate the repercussions of the fifth part of the *Discours,* and of some pages in the *Dioptrique.* When the *Discours* was published Fromondus was teaching philosophy at Louvain, and Plempius, who had begun as a physician in Amsterdam, where he had undertaken dissections with Descartes, was teaching medicine at Louvain. It should be noted that although the *Discours* had been published anonymously, Descartes' name, in Latin, was quoted in September 1638 in a treatise on medicine: in his *Fundamenta Medicinae* Plempius published, although not in their entirety,[112] the answers Descartes had given to his objections about the cause of the motion of the heart.

Soon after the exchange with Plempius and, indirectly, with Fromondus, the immediate result of the medical issues discussed in the *Discours* and the *Dioptrique* also became evident in the case of the physician Henri de Roy, known as Regius. Regius was appointed professor of medicine at Utrecht in 1638, due to his success in giving private lectures in physiology in which he applied the principles of the *Discours* and the *Essais.*[113] After an exchange of letters, Regius decided to submit to Descartes the medical theses he was formulating in order to have them defended by his students at Utrecht. Thus Regius, a teacher of medicine, was behaving as though he was a student of Descartes, as can be seen from the letters he wrote to him, as well as from Descartes' answers, from 24 May 1640 onwards, when Descartes pointed out the modifications that Regius should make to his theses. I have shown elsewhere,[114] that Descartes' contribution to the writing of these theses was so important that in 1641 he was in fact the co-author (who wished to remain hidden) of a great part of the corpus known under the title *Physiologia.* Regius later borrowed many passages from this material in his published books, particularly in his *Fundamenta Physices* of 1646. Thus Descartes' influence on Regius' *Physiologia* is to be found far beyond the three explicit references to Cartesian writings. The *Physiologia* borrows from the *Discours* the 'fire without light' (*ignis non lucidus*) in the heart, the explanation of the circulation of the blood and of the motion of the heart, and the references to 'clocks and other *automata*', and from the *Dioptrique* the affirmation that it is 'the soul that has sensory perceptions and not the body'.[115]

The *Physiologia* fits perfectly in this critical moment in the history of medicine: without giving up the traditional content and enumerations in medical treatises, it introduces major innovations, such as mechanical explanations derived from the *Discours,* and the circulation of the blood. It should be noted however that the passages concerning the circulation of the blood do not mention the name of Harvey, its inspired discoverer.[116] The reason is that these passages summarise not Harvey's book, but, with one minor difference (in the order of presentation), the proofs given to demonstrate the circulation of the blood in the *Discours.* Since Regius is following Descartes, and not Harvey directly, there is no mention in the *Physiologia* of the reference to Aristotle in the definition of the circulation of the blood. Descartes' influence is also felt in Regius' discussion of diastole and systole in their traditional meaning, which Descartes still retains instead of the new definitions given by Harvey. Following Descartes, Regius argues that the heat in the heart is a fermentation comparable to the heat 'in damp hay (*in foeno humido*)'.

As the publication of the *Discours* had already done, Descartes' contribution to the writing of these medical theses played a part in propagating the discovery of the circulation of the blood. Descartes' acceptance of the circulation of the blood, his disagreement with Harvey on the cause of the motion of the heart, both in the *Discours* and in his long epistolary discussion with the physician Plempius, his precise description of the physiology of vision in the *Dioptrique,* the 'correspondence course' given by Descartes to Regius, all lead us to regard Descartes, from 1637 onwards, as a privileged participant in medical discussion, and to acknowledge his important role in medicine in the first half of the seventeenth century. Harvey himself acknowledged the importance of the Cartesian analysis of the motion of the heart, when he discussed it in his second Reply to Jean Riolan the Younger in 1649, which contains the famous address to Descartes.[117]

Descartes' ideas on medicine were important not only during his lifetime, as shown by the letters to the physicians Meyssonnier, in 1640, on the conarium, and to Vorstius, in 1643, on the animal spirits, but their influence continued after his death, with the posthumous publication of *L'Homme* and the *Description*. When publishing these texts in 1664, the latter with the subtitle 'On the Formation of the Fœtus' (a title corresponding in part to Descartes' text), Clerselier draws attention to the Cartesian ideas on embryological questions, or, in seventeenth-century terms, on the generation of animals.[118] The complementary nature of these two texts is clear; although Descartes had given up trying to explain reproduction and embryogenesis in *L'Homme*,[119] he was to return to this question many times, which required 'free time and the convenience of practising some experiments'.[120] Thus his failure to complete the *Principia*[121] should be reconsidered, especially since one must add to these texts the unpublished papers reporting and explaining Descartes' anatomical experiments, and many pages of his correspondence, which confirm the philosopher's exceptional interest in the human body, and in the most complex questions of anatomy, physiology and embryology. In his *Primae Cogitationes circa Generationem Animalium,* Descartes reflected on the causes of the generation of monsters, and, in an important passage, evoked the laws of Nature which he had discussed in *Le Monde*. He asks: 'But, really, what more important causes can we have than the eternal laws of Nature? Is it that we would have these causes resort to some Mind? But to what Mind? Or immediately to God himself? Why are there sometimes monsters?'[122] Without trying to represent Descartes as one of Darwin's forerunners, as Fouillée tried to do in 1893,[123] the novelty of this statement is noteworthy, and all the more remarkable when contrasted with the theological or astronomical-astrological explanations, appeals to variations in the seed, and imagination found in traditional medical treatises.[124]

Descartes' attempt to rid the medical field of the difficulties and controversies he had to deal with had a lasting influence upon physicians. The reason for this is that Descartes, despite certain errors, had given a spur to experimental research, and had played a part in the vast task of founding a 'renovated' anatomy and a physiology based on new and more fruitful concepts.

Descartes' influence was felt throughout Europe. In Germany, it was apparent both in philosophy and in medicine, for instance in the teaching and writings of Johannes Clauberg, from 1651. In Paris, a *Treatise on the Fevers* was published in 1664, based on Descartes' principles, as well as *Le Monde de Mr. Descartes.*[125] The Cartesian mechanistic view, linked to the discovery of the circulation of the blood, became the prevailing view in France in demonstrating human anatomy thanks to the teaching and writings of Dionis, from 1673. Dionis also borrowed from Descartes 'the fire without light in the heart', some mechanical comparisons to explain the functions of the body, and the structure of the nerves.[126]. This Cartesian influence persisted. In 1776 for instance, P. Fabre's *Recherches sur la Nature de l'Homme*, published in Paris quotes Harvey's (written Harvée) discovery of the circulation of the blood in the section devoted to the 'Observations on the circulation of the blood'; in the same sentence, this discovery is said to entail that the body is to be considered merely as a hydraulic automaton.[127] Although Descartes is not directly quoted in this section, linking the discovery of the circulation of the blood to automata was a Cartesian notion.

Descartes is also numbered among major new physicians in Thomas Bartholin's treatise *Anatome quartum Renovata,* published in Lyons in 1677. With its division into four books, followed by four booklets linked with each of the books, the whole book proves how difficult it was to write a coherent anatomical treatise after the discoveries of the circulation of the blood and the lacteal veins. For instance, Descartes' medical ideas are quoted on the movement of the heart, on the fire without light, on the pineal gland (where the common sense and imagination are located), on the function of the crystalline humour, and on the nerves. But Bartholin also writes that no anatomist has been able to see the valves which Descartes supposed to exist in the nerves.[128]

The Italians Borelli and Baglivi borrow from Descartes the comparison of the vessels with hydrolic *automata*, and Malpighi considers Descartes as a genuine innovator in medicine, the first to give mechanical explanations of vital phenomena.[129]

Richard Lower, in his *Tractatus de Corde* (published in 1669, twenty years after Harvey's letters to Riolan), clearly quotes Descartes, but mainly to refute his theories about the motion of the heart. As for the chemist Robert Boyle, in his *Christian Virtuoso,*[130] he refers to Descartes among 'writers of dioptricks' for the study of the different parts in the eye. In 1694, the part of *L'Homme* dealing with the eye is quoted by Nicolas Hartsoeker in chs. 6 and 7 of the *Essay de Dioptrique,* published in Paris. Descartes' medical thoughts also had a complex influence on many authors of the eighteenth century, of whom Buffon is a prime example.[131]

But since Descartes' biological writings are inseparable from his reflections on what he considers metaphysics, the influence of his medical thinking was not restricted to the field of medicine. During Descartes' lifetime, the philosophical writings of Henry More question the Cartesian definition of life as something without any connection with the soul, as well as some aspects of Descartes' dualism[132]: that dualism which would also be extensively discussed, for instance, by Malebranche, who was converted to philosophy by reading *L'Homme.*

Notes

1 Some of the material used in this paper was first read at the Conference in the honour of Marjorie Grene, held at the University of Dijon in May 1995 (forthcoming publication by Jean Gayon and Richard M. Burian), and another part was read at the 'Descartes and the Renaissance' conference held at the University of Tours in March 1996 *Descartes et la Renaissance,* ed. Emmanuel Faye (Paris, H. Champion), 323–47. I referred to some parts of these two French papers in my Introduction to *Descartes: Le Monde et L'Homme* (Paris, 1996), as I also did in October 1996, when I was invited to Oxford University (Philosophical Society and Department for Continuing Education) to lecture on 'Descartes, Harvey and Renaissance Medicine', in the course organised by Michael Lockwood on 'Descartes: Philosopher-Scientist'. Marjorie Grene and Michael Lockwood are warmly thanked for their fruitful observations on a preliminary version of this paper. Many thanks to Theo Verbeek for his help in obtaining copies of Rembrandt's painting and of the anatomical theatre at Leyden, and to the librarians in the Réserve of the Bibliothèque Interuniversitaire de Médecine (BIUM) in Paris especially to Bernadette Molitor. I am deeply indebted to Stephen Gaukroger for many linguistic emendations. The remaining mistakes are mine.

2 Cf. AT vi. 1.

3 AT vi. 46 (line 26) to 55 (line 3), the fifth part beginning page 40 (line 21), and ending page 60 (line 3).

4 In his writings Descartes generally uses the word '*médecine*'. His use of this term also refers to our present conception of physiology. Descartes only made use of the term '*physiologie*', '*physiologia*' in his correspondence (cf. AT iii. 95, and iv. 240), dealing with Regius, a Dutch physician. And it was to discuss the medical theses reorganised under the heading 'physiology' that Regius consulted Descartes. These theses were called *Physiologia,* and referred to the traditional parts of medicine, which were: *anatomy, physiology* – which in those days meant the study of the natural and healthy parts of man (*'Physiologia sive cognitio sanitatis'* is the complete title of these theses) – and *pathologia.* We shall speak of these theses later in this paper.

5 AT vi. 50.

6 Kepler's name is not quoted in the *Dioptrique,* though this title refers to Kepler's *Dioptrice.*
7 For instance, the 'venous artery' corresponds to what we now identify as the pulmonary veins, and the 'arterious vein' corresponds to what is now known as the pulmonary artery. For more details, see Annie Bitbol-Hespériès, *Le Principe de Vie chez Descartes* (Paris, 1990), 57–63.
8 Cf. for instance Laurentius (André Du Laurens), who agrees on this theme with all others anatomists: *Historia Anatomica* (Frankfurt, 1600), 351. Cf. *L'Histoire Anatomique,* trans. F. Sizé (Paris, 1610), Book IX, ch. 10, p. 1051 and ch. 11, p. 1062.
9 Cf. *L'Histoire Anatomique*, op. cit., qu. VII, p. 1068.
10 AT vi. 46.
11 See *Le Principe de Vie chez Descartes,* op. cit.
12 See to Beverwick, 5 July 1643, AT iv. 4; To Newcastle, April 1645, AT iv. 189.
13 See Part I, art. 7.
14 AT xi. 239.
15 Cf. *Prelectiones Anatomiae Universalis.* There are two English translations of Harvey's manuscript: C.D. O'Malley, F.N.L. Poynter, F.K. Russel, eds. *Lectures on the whole of Anatomy* (Berkeley, 1961), and G. Whitteridge, ed., *The Anatomical Lectures of W. Harvey* (London, 1964).
16 AT i. 102.
17 For Descartes as an 'amateur' in medicine, see for instance, Lindeboom, *Descartes and Medicine* (Amsterdam, 1979), 70 and 81. Taking an opposite view to Lindeboom's statement is Stephen Gaukroger's, in his *Descartes, an Intellectual Biography* (Oxford, 1995), where Gaukroger notes that Descartes' 'extensive anatomical investigation . . . shows him to have been a thorough and careful observer' (270).
18 For instance Plempius, Regius, and Vorstius, who taught medicine in the Low Countries, and Meyssonnier, a French physician.
19 Cf. *The Circulation of the Blood, two Anatomical Essays* by W. Harvey, ed. K.J. Franklin (Oxford, 1958), 65–66, 153–154.
20 AT i. 137.
21 AT ii. 525.
22 *De Humani Corporis Fabrica* (Brussels, 1543), Foreword.
23 Ibid., Foreword, '. . . *emortuam humani corporis partium scientiam*'.
24 *Andreae Vesalii Bruxellensis, Epitome Anatomica, Opus Redivivum,* cui accessera notae et commentaria, P. Paaw Amsteldamensis, in Lugduno Batava Academia Professoris anatomici, apud Henricum Laurentii, bibliopolam.
25 In The Hague (Mauritshuis). On this painting, see my paper, 'Connaissance de l'Homme, Connaissance de Dieu', in *Les Etudes Philosophiques* vol. 4 (1996), 507–33: esp. 522–6.
26 Tulp (1593–1674), whose actual name is Claes Pieterszoon, or Nicolaus Petreus. This public anatomical demonstration is the second one in Tulp's career.
27 Cf. William S. Heckscher, *Rembrandt's Anatomy of Dr. Nicolaas Tulp* (New York, 1958), 65.
28 Cf. Latin and German editions of the *Epitome.*
29 Cf. letter to Mersenne, 13 November 1639, AT ii. 621.
30 AT i. 263.
31 Letter to Meyssonnier, 29 January 1640, AT iii. 19–20; and to Mersenne, 1 April 1640, AT iii. 47–8.
32 AT xi. 120.
33 Ch 4, pp. 25–6 of first edition.
34 Cf. *Prelectiones Anatomiae Universalis.*

35 AT iv. 555.
36 See my notes to the second volume of the forthcoming Pléiade edition of Descartes' *Primae Cogitationes circa Generationem Animalium.*
37 For further details, see *Le Principe de Vie chez Descartes,* op. cit., p. 91–4.
38 See H.B. Adelmann, *The Embryological Treatises of Hieronymus Fabricius* (Ithaca, N.Y., 1942), Introduction: i. 23.
39 Cf. *Etudes sur le Rôle de la Pensée Médiévale dans la Formation du Système Cartésien* (Vrin, 1930, 4th edn. 1975).
40 AT i. 254.
41 Cf. *Historia Anatomica,* 297 in Latin edn., 859 in French trans., op. cit.
42 Cf. AT vi. 41, *Le Monde,* AT xi. 3.
43 See *Le Monde,* ch. 4, *Principia,* II, art. 33, and IV, 65, and *Météores* Disc I and II on subtle matter.
44 Jacques Roger, *Les Sciences de la Vie dans la Pensée Française au XVIIIe Siècle* (Paris, 1971), 148.
45 *De Occulta Philosophia libri tres,* 1533, lib. II, cap. XXVII, pages CIIII, and CV.
46 Fludd, *Utriusque cosmi,* II (De microcosmo interno), 1619, Tractatus I, lib. VIII, p. 176, and I, sect. I, lib. III, p. 83: 'orbis solis, seu cordis', and p. 105.
47 Cf. *Physiologia,* IV, 1602, *De spiritibus et innato calido,* 94–5.
48 Cf. *Paralipomena ad Vitellionem,* cap. I, prop. XXXII, and *Astronomia Nova,* ch. XXXIII.
49 Cf. *L'Histoire Anatomique,* op. cit., livre I, ch. II, p. 9.
50 Cf. *L'Histoire Anatomique,* op. cit., livre IX, ch. X, p. 1051.
51 For instance by L. Chauvois, *W. Harvey* (Paris, 1957), 64–5 and 184.
52 Cf. AT i. 322.
53 *De Motu Cordis,* ch. 2.
54 AT xi. 243.
55 Cf. *De Motu Cordis* (1628 edition)*,* 51, 54.
56 Cf. Part V, and letter to Plempius, 15 February 1638, AT i. 527 and AT xi. 241–5. For further details, see *Le Principe de Vie chez Descartes,* op. cit., 68–71.
57 Cf. first edn., 42. The English translations are from the Whitteridge ed. (Oxford, 1976).
58 Cf. Fludd, *Medicina Catholica,* 1619. Walter Pagel was the first to draw attention to Fludd with reference to Harvey's discovery: W. Pagel, 'Religious motives in the medical biology of the XVIIth Century', *Bulletin of the History of Medicine,* vol. 3 (1935), 277. Cf. W. Pagel, *William Harvey's Biological Ideas* (Basel, 1967), 114–15.
59 W. Pagel, *William Harvey's Biological Ideas,* op. cit., 113.
60 AT vi. 47.
61 AT vi. 48.
62 Cf. *De Motu Cordis,* cap. 6, 8, 17.
63 Cf. C.D. O'Malley, *Andreas Vesalius of Brussels* (Berkeley, 1964), 139.
64 Cf. 1543 edition, for instance in the foreword, and Bk I, cap. IV, p. 11, cap. V, p. 17 ('capitis structura').
65 The word 'admiratio' and words derivating from it can be frequently found, see for instance in the first edition, 88, 89, and lib. VI, cap. I, p. 570.
66 Ibid., 26 '. . . rerum Opifex', 58, *passim.*
67 Cf. first edition, 57: 'Naturae indorsi creatione industria', 58, 59, *passim.*
68 Ibid., '. . . Naturae providentiam in digitorum articulis contemplari . . .' (123).
69 Ibid., lib. I, cap. XIX, p. 88 and cap. XXVII, p. 122.
70 Ibid., lib. II, cap. II on the muscles in the hand, p. 219.
71 Vesalius wanted his treatise to be useful both to physicians and to artists. But the influence of his treatise went far beyond and showed the connection between things medical and ecclesiastical. In 1550, Henry Bullinger, the Swiss

reformer, dedicated sermons to King Edward VI, the English sovereign. God, wrote Bullinger, is known by his works, '. . . and the workmanship or making of man, which Lactantius and Andreas Vesalius have passingly painted out for all men to see . . ..' Cf. M.H. Fisch, 'Vesalius in English State Papers', *Bulletin of the Medical Library Association,* vol. 33 (1945), 253, n. 54. After his reading of Vesalius' treatise, Philip Melanchthon, Luther's close colleague and the main reformer of teaching in Protestant Universities, wrote in 1552, in a copy of the *Fabrica,* a poem about cosmology, anatomy and theology. In the twenty-eight lines of his poem, he wrote about God who 'shaped', 'maintains and fashions everything in logical design' in the world, and about the human body: '. . . the body's several parts/Came not together aimlessly as if devised by chance:/With purpose God assigned to each its own allotted task/And ordered that man's body be a temple to Himself/So Holy Wisdom casts its rays within our human minds/And sways our thoughts with light divine emitted from His word. . . .' Cf. Philippus Melanchthon, *De Consideratione Humani Corporis,* Flyleaf prefixed to the *Fabrica* now in the USA Army Medical Library, quoted in D.M. Schullian, 'Old Volumes Shake Their Vellum Heads', *Bulletin of the Medical Library Association,* vol. 33 (1945), 440. The same idea of the human body as a temple appears in Melanchthon's *Oratio de Arte Medica,* in *Encomia Medicinae Des. Erasmi Roterodami, Hieronymi Cardani, Philippi Melanchthonis* (Rotterdam, 1645), 130–1.

72 Cf. *De Motu Cordis,* chs. 6, 8 (on the final cause of the movement of the heart p. 42), and ch. 17.

73 AT xi. 36–7.

74 See, for instance Salomon de Caus, *Les Raisons des Forces Mouvantes avec Diverses Machines tant Utiles que Plaisantes auxquelles sont adjoints plusieurs Dessins de Grottes et Fontaines* (Frankfurt, 1615).

75 AT vi. 59.

76 Cf. AT xi. 153, 268, AT iii. 262.

77 AT vi. 57.

78 AT vi. 45–6.

79 AT vi. 46.

80 Cf. *L'Histoire Anatomique,* op. cit., 1.

81 *Institutiones Anatomicae* (1632), *Anatome quartum renovata* (1677).

82 Cf. *L'Anatomie de L'Homme suivant la Circulation du Sang et les dernières Découvertes* (Paris, 1694), 125.

83 *Meditationes,* AT ixA. 19, and vii. 24.

84 Cf. *Discourse,* AT vi. 59, and end of sixth Meditation.

85 Cf. *Passions,* art. 2 and 6, *Description,* Foreword.

86 *Passions,* art. 139.

87 AT vi. 54.

88 *Le Monde*, AT xi. 107, 109 and 110.

89 Cf. Laurentius, *L'Histoire Anatomique,* op. cit., book XI, ch. VIII, p. 1316. See also the *Anthropographia* by Riolan the Younger (Paris, 1618), lib. IV, and the French translation by P. Constant (Paris, 1629), pp. 592–5.

90 Letter of 31 March 1638, AT ii. 86.

91 Cf. *Paralipomena ad Vitellionem,* cap. V, 2.

92 AT i. 102.

93 I disagree here with W. Shea, *The Scientific Career of René Descartes* (Canton, 1991), 109–11. Allen G. Debus was inspired by a previous paper written by W. Shea about the link between Descartes and the Rosicrucians, in his book *The French Paracelsians* (Cambridge 1991), 67–70. On these points, see my 'Les Olympica et la Vocation Scientifique de Descartes', in Fernand Hallyn, ed., *Les Olympiques de Descartes* (Geneva, 1995).

94 AT vi. 129. Cf. *L'Homme,* AT xi. 175–7.
95 AT vi. 129.
96 AT vi. 1. Cf. my 'Descartes et Regius, leur Pensée Médicale', in Theo Verbeek ed., *Descartes et Regius, Autour de l'Explication de l'Esprit Humain* (Amsterdam, 1993), 47–68.
97 AT vi. 108.
98 Cf. Bauhin, *Theatrum Anatomicum,* 739–40 in 1605 edn. and 387 in 1621 edn., and Laurentius, *L'Histoire Anatomique,* Book XI, ch. V, and qu. V, pp. 1308 and 1345.
99 Cf. Laurentius, *L'Histoire Anatomique,* Book I, beginning of the first chapter; see also C. Bauhin, *Theatrum Anatomicum* (1621 edn.), praefatio, p. 2, about the theme of man '*alii vero rerum omnium finem*'.
100 AT vii. 55; AT vii. 309. Descartes will also discuss the conception of man as 'the end of creation' later: cf. to Chanut, 6 June 1647, AT v. 53–54, and *Principia,* III, arts. 2–3.
101 AT vii. 375.
102 Cf. letter to Mersenne, 15 April 1630, AT i. 144, and *Description,* AT xi. 223. On this point, see my 'Connaissance de l'Homme, Connaissance de Dieu', op. cit.
103 *L'Histoire Anatomique,* op. cit., Book I, ch. I, III, V, VI, pp. 1, 13 and 21–8.
104 See *Theatrum Anatomicum,* where the 'know thyself' is quoted in Greek. Cf. Epistola dedicatoria, p. 4 (verso) in 1605 edn., and p. 2 in 1621 edn.
105 Cf. for instance *De Usu Partium,* lib. II, cap. X.
106 Cf. the French translation already quoted by F. Sizé, Book XI, ch. III, p. 1301.
107 On these detailed prints of 1609 and 1610, see my 'Connaissance de l'Homme, Connaissance de Dieu,' op. cit.
108 AT vi. 55.
109 Cf. *De Usu Partium,* Book I-II, Book III, caps.1, and 10, and Book XVII, cap. 1.
110 Letter from Fromondus, 13 September 1637, AT i. 406.
111 Cf. letters from Fromondus to Plempius, 13 September 1637, AT i. 406; from Descartes to Plempius for Fromondus, 3 October 1637, AT i. 420, and *Principia,* IV, art. 196.
112 Plempius will only publish these letters in their entirety in 1644, in a second edition, after Regius' criticisms. They will also be republished in 1654.
113 Cf. letter to Mersenne, 23 August 1638, AT ii. 334.
114 'Descartes et Regius, leur Pensée Médicale', op. cit., 47–68.
115 AT vi. 109.
116 Nor is Harvey referred to either in *Fundamenta Physices* or in *Philosophia Naturalis.*
117 Cf. K.J. Franklin, *The Circulation of the Blood,* op. cit., 65–6 and 153–4.
118 Cf. the editions of 1677, and 1680, and the translations into Latin (a new one for *L'Homme,* whose first edition appeared in 1662, joined with *La Formation du Fœtus*), in 1686 et 1692. Cf. also the 1697 Frankfurt edition, *Opera philosophica.*
119 Letter to Mersenne, June 1632, AT i. 254.
120 Letter to ***, 1648 or 1649, AT v. 261.
121 See Part IV art. 188: AT ixB. 309.
122 AT xi. 524.
123 See his *Descartes* (Paris, 1893), 67.
124 Cf. *L'Histoire Anatomique,* op. cit., 877. Cf. A Paré, *Le Livre des Monstres,* op. cit.
125 Its author is Rohault.
126 Cf. *L'Anatomie de L'Homme suivant la Circulation du Sang,* op. cit., for instance, 287, 302, 496, 503.
127 Cf. *Recherches sur la Nature de l'Homme, considéré dans l'état de santé et dans l'état de maladie* (Paris, 1776), 50–1.

128 Cf. in particular, 364–5, 384, 497, 520, 660–1, and 664.
129 *Opera posthuma*, 1662, introductory discourse.
130 Cf. *The Works of the Honourable Robert Boyle*, 6 vols. (London, 1772), vi. 737.
131 See J. Roger, *Buffon* (Paris, 1989).
132 Cf. my paper, 'Le Dualisme dans la Correspondance entre Henry More et Descartes', in *Autour de Descartes, le Dualisme de l'Ame et du Corps* (Paris, 1991), 141–58.

16 The resources of a mechanist physiology and the problem of goal-directed processes

Stephen Gaukroger

One of the principal tasks of a mechanist natural philosophy in the seventeenth century was the elimination of teleology. In the case of mechanics, optics, and cosmology, there were, outside the question of the formation of the Earth, few reasons to question this approach once Aristotelianism had been abandoned. Physiology was a different matter, however, and among the phenomena that a mechanised physiology had to deal with were a number of processes that seemed clearly goal-directed. Here at least, it was not a question of Aristotle's misguided concern to provide teleological explanations where they were not needed, but rather that of how one could possibly avoid reference to goals in explaining these processes.

I want to examine the resources used by Descartes in his development of a mechanist physiology to account for two processes that had traditionally been conceived as goal-directed. The first is his account of the development of the foetus, where he pursues a programme designed to show that what had traditionally been seen as a goal-directed process need not be thought of as goal-directed at all, and could be construed in terms of straightforward mechanical causation. The second occurs in his treatment of perceptual cognition in animals – and in humans in cases where the intellect is not operative, that is, where it is simply a case of psychophysiology – where he does not attempt to show that perceptual cognition does not occur, but rather invokes a kind of receptive capacity which stretches what one might normally think of as the limits of explanations that have recourse only to mechanical causation.

The aims of a mechanistic physiology

Before we can appreciate the strengths and limitations of these resources, it is important that we ask about the aim of a mechanised physiology, that is, what Descartes hoped to achieve by such a programme. Descartes' commitment to mechanism extends far beyond physiology, and the most important statement of his mechanist physiology, the *Traité de l'Homme*, is the continuation of a work providing a mechanist account of optics and cosmology, the *Traité de la Lumière*, also known by the generic title *Le Monde*. *Le Monde* set out to show how optical and cosmological phenomena can be explained in terms of a theory of matter and two basic physical principles, centrifugal force and the principle of rectilinear inertia. His theory of matter allows no qualitative distinction between types of matter, it allows no internal forces or activities, and it explains various differences between the properties of things in terms of three sizes of matter, the largest making up the planets, the second making up fluids such as the air and the regions between planets, and the smallest filling up the regions between the boundaries of the first and second kinds, which are generally speaking corpuscular, and also making up the sun.[1] The most important feature of Cartesian matter from the point of view of mechanism is its inertness. This was a constraint the full implications of which Descartes had learned from Mersenne, for it was the version of mechanism that Mersenne was developing in various works in the mid-1620s that largely shaped Descartes' understanding of the natural-philosophical issues underlying mechanism.[2] Mersenne had been particularly concerned to rebut various forms of Renaissance naturalism, which had obscured the distinction between the natural and the supernatural, and had conceived nature generally as animate in varying degrees, having numerous powers and forces by which natural processes were effected. One particular danger that he perceived in the construal of nature as an 'active realm' along naturalist lines was that the need for divine activity would ultimately be rendered otiose. Unable to counter these forms of naturalism by relying on traditional scholasticism – for the Aristotelian doctrine of form was part of the naturalist armoury – he advocated a strict separation between an active supernatural realm and a completely inert natural realm, stripping the latter not just of the offending sympathies and powers of the naturalists, but also of Aristotelian forms and qualities.

Descartes employs this notion of matter not only in his physical theory, but also in his account of physiology. There are three kinds of approach to which his mechanist account can be seen as an alternative. These attempt to provide an account of physiology that aims to explain various functional differences between organs either, first, in terms of qualitatively different kinds of matter, or, second, in terms of some non-material principle guiding those functions, or, third, in goal-directed terms which cannot be captured mechanistically. In the first case, what was usually invoked was the traditional doctrine of the four elements – earth, air, fire, and water – but Descartes had, in *Le Monde*, already questioned both the basis for this doctrine and whether the accounts it produced could have any explanatory value, whether they could actually have informative content; and he had offered his own accounts of phenomena such as burning, and the different physical properties of solids and fluids, in terms of his much more economical single matter theory. At a general level, the argument is that invoking the traditional theory of the elements explains nothing, and the cases they are invoked to explain in physical theory can actually be accounted for fully in terms of a single type of matter, material extension.[3] When we turn to physiology, the same considerations apply. Why try to account for differences in physiological function in terms of a theory of matter which would not explain anything anyway, and which can be replaced by something much more economical?

In the second case, a parallel set of considerations holds. Instead of a theory of elements, what are invoked are various classes of 'soul': vegetative souls, sensitive souls, and rational souls. These are supposed to capture various qualitative differences that emerge as we ascend the chain of being from inanimate matter, to vegetable life, to animal life, to human beings; or alternatively, as we ascend from those functions we share with plants, to those we share with animals, to those that are distinctively human. Descartes certainly thinks that distinctively human capacities require the postulation of a separate soul, but the postulation of a hierarchy of souls – and more specifically, the postulation of a 'sensitive soul' to account for animal sentience – is a different matter. First, it is unnecessary, since one can, Descartes believes, explain vegetable and animal capacities simply in terms of matter. Second, the postulation of a hierarchy of souls does not actually explain anything: it does nothing more than label the stages at which various differences are considered to emerge, while giving the impression that the cause of the difference has been identified. Third, a hierarchy of souls obscures the all-important distinction between the soul and the body, suggesting that the differences may be ones of degree, something that Descartes singles out for criticism in his theory of the passions.[4]

The third case, that of the apparent goal-directedness of certain physiological processes, is the most serious challenge to a mechanist physiology, and the cases of the development of the foetus and perceptual cognition are the most problematic kinds of case for a mechanist account. Descartes deals with both in some detail, and, as we shall see, his treatment of them differs considerably, highlighting two very different kinds of strategy available within a mechanist physiology. His account of embryology is radically revisionary and effectively eliminates any element of goal-directedness in foetal development. His account of perceptual cognition, on the other hand, aims to 'save the appearances' to a large extent, and is reductionist, in that nothing other than mechanical processes are involved. These mechanical processes, however, have a level of structuring imposed upon them that allows for recognitional capacities, something which Descartes shows, at least at an elementary level, not to be beyond the capabilities of a mechanist theory: the aim is to show how function can be generated purely within the resources of mechanism.

It is important, in considering these matters, to understand where the novelty of Descartes' attempt to mechanise physiology lay in. It did not lie in construing psycho-physiological functions corporeally. Many psycho-physiological functions had been construed corporeally before Descartes by writers on physiology, and indeed there had been an extensive concern from Galen onwards with the localisation of particular faculties in the brain. There was even an orthodox tradition, dating back to the Church Fathers, of construing thought in corporeal terms, a tradition which the 'theologians and philosophers' who compiled the sixth set of objections to Descartes' *Meditationes* describe explicitly and approvingly as the 'soul thinking . . . by means of corporeal motions'.[5] Descartes' aim was to show that a number of psycho-physiological functions that had traditionally been recognised as being corporeal could be accounted for in a way that did not render matter sentient. That is the novel part of the programme. What is original about Descartes' project is not that it construes the faculties in corporeal terms, but his attempt to show that construing them in corporeal terms did not contradict the central tenet of mechanism that matter was inert.

Finally, it is worth asking just what picture of biological entities emerges from the more revisionary aspects of Cartesian mechanist physiology. Descartes speaks of animals as 'automata', a term that also covers human bodies when not considered as animated by a soul. The terminology is misleading, however, for in the seventeenth century it meant little more than a 'self-moving thing', and John Cottingham has reminded us in this context that Leibniz, 'defending his claim that we possess "freedom of spontaneity" speaks of the human soul as a "kind of spiritual automaton", meaning no more than that its action-generating impulses arise solely *ad interno*, and produce effects without the intervention of any external cause'.[6] Indeed, the terminology of machines, which carries with it the strongest connotations for our understanding of what a mechanistically construed animal might be like, is also somewhat misleading here. We tend to think of seventeenth-century machines as rigid wooden and metal clockwork constructions, like the famous Strasbourg clock. On this conception, 'animal machines' come out looking like the metal robots of twentieth-century imagination. But the machines that Descartes takes as his model are hydraulically powered statues and mechanically driven fountains: the kinds of devices he describes in *L'Homme*[7] resemble, and probably derive from, the hydraulically powered devices in the underground grottoes at the Saint-Germain gardens, which Descartes was certainly familiar with from illustrations,[8] and which he may well have known at first hand. He mentions the analogy with clocks in the *Discours de la méthode*,[9] but there is no evidence that clocks ever formed a model for a mechanistic physiology. Just as in *Le Monde*, where bodies are carried along in fluids, so in *L'Homme* the kind of image Descartes' model conveys is that of fluids being pushed through tubes, not wheels working cogs, and this has a much more intuitively 'organic' feel to it. The difference between an animal as traditionally conceived and a Cartesian automaton is not a difference between soft, fleshy organic entities and clockwork robots, but a conceptual difference between how physiological processes are to be modelled.[10]

Development without teleology: the formation of the foetus

In *Le Monde* and in Part IV of the *Principia*, Descartes offered an account of the formation of the Earth that attracted wide criticism, especially in England. He was accused of 'Epicureanism', for on his account, the processes that led to the formation of the Earth were either chance processes or were driven by necessity, and what was conspicuously absent was any providential guidance.[11] Providential guidance introduces an element of goal-directedness into the question: the Earth is there for a specific reason and is formed so as to serve a particular function, as a home for human beings, at least until the Last Judgement. The argument was that if we ignore that function, we will fail to understand what the Earth is, just as surely as if we try to understand a watch without realising that it is designed to keep the time.

There are a number of similarities between Descartes' account of the formation of the Earth and his description of the formation of the foetus in the *Description du corps humain*. Both had traditionally been construed as intrinsically goal-directed processes, and it is important to appreciate here that Descartes' concern is not with goal-directedness as such, but with intrinsic goal-directedness. He does not deny that God guides the development of the embryo any more than he denies that God guides the formation of the Earth. But such extrinsic goal-directedness simply does not fall within the domain of natural philosophy for Descartes. It would do so only if the goal-directedness were somehow internalised by the body so guided, but this would be to allow processes in the body that were incompatible with the inertness of matter. At one level, Descartes is not denying that there is a question as to why matter behaves in such a way that the foetus develops into an adult of a particular species. What he is saying is that the explanation for that is not something *internal* to the development of the foetus but *external* to it: God made it so. Nor is this necessarily an unorthodox position. Although he does not do so, Descartes could easily have cited Augustine, who writes in the *City of God* (12. 26):

> We do not call farmers 'creators' of crops, since we are told, 'The planter does not matter, nor does the waterer. It is God who matters, for it is he who makes things grow' [1 Cor. 3.7]. We do not even ascribe creative power to the earth, although it is clearly the fruitful mother of growing things, promoting their growth as they burst out into shoots, and holding them safely by the roots; for as we are also told, 'God gives to the seed a body of his own choosing, its own body to each seed' [1 Cor. 15.38]. We must not attribute to a woman the

> creation of her child, but instead to him who said to his servant, 'I knew you, before I formed you in the womb' [Jer. 1.5].

In other words, God is the only final cause. What Descartes is concerned with in his natural philosophy are internal or intrinsic causes, and these are missing, for Augustine as for Descartes, in the case of foetal development.

What Descartes denies, then, is intrinsic goal-directedness. Such intrinsic or internally generated goal-directedness is a feature of Aristotelian natural philosophy, where it was thought to be characteristic of any natural process. There, organic processes, such as a seed developing into a tree, and inorganic processes, such as the fall of a body to the earth, are put down to some intrinsic goal-directedness. Mechanism dismantles the conceptual apparatus whereby processes are construed as being goal-directed, because it removes the doctrine of forms, which is crucial to the notion of something striving to realise its natural state. It does this not just in the cases where goal-directedness seems an artificial way to construe what happens once Aristotelianism has been abandoned, however, but also in cases where this remains a natural way of construing what occurs, such as in the development of the foetus.

Most biological processes can be thought of in goal-directed terms: nutrition, respiration, excretion, sleep, etc. But then many purely physical processes can be thought of in goal-directed terms, and Aristotle had thought that the explanation of the fall of heavy bodies to the ground had to display the goal-directedness of this process: bodies fall to the ground because this is their natural place, and when they are unconstrained, it is in the nature of heavy bodies to behave in this way. This raises the problem of where we draw the line. We may concede that a process can be described in terms of a goal without conceding that goal-directedness plays any genuine part in explaining the process. Unless we think that teleology plays a part in any natural organic process, for example, we will not be inclined to think that growth in adolescents or adults requires explanation in terms of ends or goals. On the other hand, we may be inclined to think that the development of the foetus does require an explanation in terms of ends or goals: it develops in this way because it is developing into a horse, or a person, or a bird. In the middle of these two is a grey area. We can think of Descartes' strategy as pushing foetal development into the grey area, in which case the question of the right kind of explanation will no longer be judged by a priori considerations about whether goals are relevant, but by how effective whatever concrete explanation one comes up with is in accounting for the detail.

More schematically, although Descartes does not lay out his plan for dealing with this question explicitly, it seems clear that a threefold strategy must lie behind any thoroughgoing mechanist approach to embryology. First, ordinary growth is accounted for in a way that makes no reference to goals. Second, the process of formation and maturation of the foetus is treated simply a species of growth: it involves a significantly greater increase in complexity and internal differentiation of parts than the process of growth from childhood to adulthood, of course, but this in itself does not make it qualitatively different. Third, the mechanist must show how the development from a low degree of complexity and internal differentiation to a high degree of complexity and differentiation is something that can be handled in mechanistic terms.

What this strategy allows one to do is to provide a general account of growth, in terms of how raw material is introduced into the organism from outside and transformed into the kinds of highly differentiated material making up bones, blood, muscle, etc. Then, having done this, one shows how the kind of account developed in this way can be extended to the case where the organs are not being built up but are actually being formed anew.

The phenomenon of growth, in the less problematic non-foetal case, comes under the maintenance of bodily organs. This is covered in the third section of the *Description du corps humain*, which deals with nutrition.[12] Descartes starts by arguing that the organs of the body are nourished by blood from the arteries. To understand this more distinctly, he tells us,

> we must bear in mind that the parts of those living bodies that are maintained through nourishment, that is, animals and plants, undergo continual change, in such a way that the only difference between those that are called *fluids*, such as the blood, humours and spirits, and those that are called *solids*, such as bone, flesh, nerves, and membranes, is that the latter move much more slowly than the others.[13]

That all the parts of the body move, those of the solid bodily members just as much as the parts of bodily fluids, is a crucial point, increasing the degree of homogeneity of the matter making up the body, and hence making it easier to account for the transformation of nutrients into the fabric of the body. This constant motion causes rubbing, which in turn can cause various bodily parts to become smaller or larger. At this point we get the explanation of growth, change of bodily shape, and ageing of the body:

> When one is young, for example, because the filaments that make up the solid parts are not joined to one another very firmly, and the channels along which they flow are quite large, the motion of these filaments is not as slow as when one is old, and more matter is attached to their roots than is detached from their extremities, which results in their becoming longer and stronger, and their increase in

> size is the means by which the body grows. When the humours between these filaments do not flow in great quantity, they all pass quite quickly along the channels containing them, causing the body to grow taller without filling out. But when these humours are very abundant, they cannot flow so easily between the filaments of the solid parts, and in the case of those parts that have very irregular shapes, in the form of branches, and which consequently offer the most difficult passage of all between the filaments, they gradually become stuck there and form *fat*. This does not grow in the body, as flesh does, through nourishment properly speaking, but only because many of its parts join together and stick to one another, just as do the parts of dead things. And when the humours become less abundant, they flow more easily and more quickly, because the subtle matter and the spirits accompanying them have a greater force to agitate them, and this causes them little by little to pick up the parts of the fat and carry them along with them, which is how people become *thin*. And as we get older, the filaments making up the solid parts tighten and stick together more closely, finally attaining such a degree of hardness that the body ceases entirely to grow and even loses its capacity for nourishment. This leads to such an imbalance between the solid and the fluid parts that age alone puts an end to life.[14]

Descartes then turns to the question of how the requisite form of nourishment gets to the right part of the body. This is, of course, something one might be inclined to think of in goal-directed terms, but Descartes' approach is resolutely mechanical. Can we seriously suppose, he asks, that each bodily part can choose and guide the parts of the food to the appropriate place? To do so would be 'to attribute more intelligence to these than even our soul has'.[15] Rather, he argues, there are only two factors that can be responsible for the movement of nutrients to the appropriate place: their initial position in relation to that organ, and the size and shape of the pores in the membranes through which the nutrients pass, and in this connection Descartes looks at the paths which the blood takes around the body and discusses the sieving effects of the pores.

At this point, Descartes tells us that we will have a better knowledge of how nutrition works if we consider 'how the bodily parts are formed from seed',[16] and we are thereby launched into the formation of the foetus via a consideration of nutrition – just about as mechanist a route as is possible. The reproduction of plants, which Descartes treats as asexual, is distinguished from the conception of animals, which is sexual, comprising the mixing of male and female fluids, 'which act on each other like a kind of yeast, heating one another so that some of the particles acquire the same degree of agitation as fire, expanding and pressing on the others, and in this way putting them gradually into the state required for the formation of parts of the body.'[17] The shift from a liquid state to one on a par with fire is simply an increase in the degree of fluidity in Descartes' natural philosophy; the point in the present context is that the materials from which the foetus is initially formed are as fluid as possible, allowing them to take on any form.

The explanation of the differentiation of these parts now begins. The initial form of differentiation occurs due to the heat generated in this mixture, 'which acts in the same way as does new wine when it ferments, or as hay which is stored before it is dry, causing some of the particles to collect in a part of the space containing them, and then makes them expand, pressing against the others'.[18] This is how the heart begins to be formed. But because the tiny parts of matter which have been expanded by the heat in this way tend to continue in their movement in a straight line, following Descartes' principle of rectilinear inertia, and because the heart, which is now forming, resists them,

> they slowly move away and make their way to the area where the brain stem will later be formed, in the process displacing others which move around in a circle to occupy the place vacated by them in the heart. After the brief time needed for them to collect in the heart, these in turn expand and move away, following the same path as the former. This results in some of the former group which are still in the same position – together with others that have moved in from elsewhere to take the place of those that have left in the meantime – moving into the heart. And it is in this expansion, which occurs thus in a repeated way, that the beating of the heart, or the pulse, consists.[19]

We are then taken through an explanation of the formation of the spine, pulmonary artery, pulmonary vein, the brain, the sense organs, and so on, with occasional explanations of how the mechanical processes as described account for various observed phenomena, such as the colour of the blood.

The basic explanatory tools are: the fermentation-like process that produces heat and a breakdown of matter when the seeds of the two sexes are combined; the ways in which these parts subsequently recombine simply under the action of heat and the expansion and increased pressure this produces; the rectilinear tendency of the parts projected under this pressure and the barriers to a rectilinear motion, causing various forms of branching and the collection of matter at different termini of this branching depending on degree of fluidity, degree of agitation, size of pores in the membranes formed, and various other mechanically conceived variables.

This account is designed to explain the development of the veins, arteries, and epigastrics in the foetus in terms of the initial state of the combination of 'seeds', the natural tendency of matter to move in the straight line, and the branching and conglomerations of matter that result from the constraints on its motion. The final part of the *Description* then turns to the formation of organs, or, more specifically, to the heart, brain, muscles, and the various skins and membranes that enclose organs. There is little to be gained from considering each of these in detail, but we can perhaps consider his account of the formation of membranes as indicative of his approach.

> When the arteries and the veins begin to be formed, they still have no membrane covering them, and are just tiny channels of blood spreading this way and that in the seed. But in order to understand how their skins are formed, and following on from this their solid parts, it should be noted that I have already distinguished above between the particles of blood that rarefaction in the heart separates from one another, and those that the same action joins together, squeezing and crumpling them in such a way that several small branches are formed around them which easily attach one to the other. Now the first are so fluid that they do not seem to be able to enter into the composition of those parts of the body which harden; but except for the spirits that go to the brain, and which are formed and made up from the finest, all the others should just be considered as vapours or serosities of the blood, from which they are continually issued, via all the pores they find along the arteries and the veins through which they pass. Thus there only remain the other particles of blood (those that make it appear red) which properly serve to make up and nourish the solid parts; nonetheless, they do not serve this role while they are severally joined together, but only when they have come apart from one another, for in going backwards and forwards several times through the heart, their branches gradually break, and finally are separated by the same action that had joined them. Then, because they are less readily moved than the other particles of blood, and because some branches usually remain, they come to a halt against the surface of the passages through which they pass, and thus they begin to form their skins. Then, those that come after these membranes have begun to form are joined to the first, not indiscriminately in every direction, but only from the side where, without preventing the flow of serosities, there can be vapours, and also other finer matter, namely the first two elements that I described in my *Principia*, which run incessantly through the pores of these membranes; and gradually joining themselves to each other, they form the tiny filaments of which I said above all solid parts were made.[20]

The point here is not to assess how the details Descartes gives match up with those provided by modern developmental physiology, but to ask whether, in making no reference to intrinsic ends or goals, he has deprived himself of an essential ingredient in any satisfactory explanation of this development. Ideally the kind of picture he wants, as I have indicated, is that where the development of the foetus can be seen as a variant on the assimilation of nutrients, like adolescent growth, getting fat, and getting thin. No one would see putting on weight as a process directed towards a state in which one is fat: this would be to get the causality the wrong way around. Similarly, it is the (mechanistically construable) chemical and mechanical processes that occur in the foetus that cause it to develop into an adult of a particular species, not the fact that it is going to develop into a member of a particular species that causes the particular chemical and mechanical processes to occur in the way they do.

Perceptual cognition

Descartes has a specific quarrel with the attempt to treat perception as a goal-directed process: it is not just that thinking of goals gets us nowhere, as was the case in embryology. Rather, trying to think through perception in terms of its goals points us in a direction that is demonstrably wrong. Aristotle had maintained that we have the sense organs we do because they naturally display to us the nature of the world, and his account of the optics and physiology of perception turned around what he took its function to be. Among other things, the optics and physiology had to be construed in such a way as to yield perceptual images that resembled what was perceived. The optics and physiology that Aristotle's account yielded turned out to be completely wrong, however, as Descartes knew, and his own account of perception, in the *Regulae* for example, starts from a new understanding of the optics and physiology of vision and uses this understanding to explore what form visual cognition might take.[21]

But, contrary to what is the case in embryology, the question of goal-directedness cannot simply be dismissed as something extrinsic in the case of perceptual cognition. The mother's body just needs to process ingested material in the right kind of way for the foetus to be able to develop. But perception is not merely a question of processing pineal excitations in the right kind of way, it is also a question of responding to these pineal excitations in the right kind of way: in particular, in the case of visual cognition, responding in such a way that the organism perceives light.

Descartes' strategy here must be different from the strategy that underpins his account of foetal development. Visual cognition involves cognitive response. This is not a problem for an account that construes the sense organs primarily in terms of their function, that subordinates structure to function, as Aristotle's account did. Descartes wants to subordinate function to structure, he wants there to be nothing more to function than what an examination of structure reveals. The problem in perceptual cognition is to recognise the goal-directedness of perceptual cognition – the goal is cognition, the means perception – without rendering this a teleological process. It is basically the problem of capturing the idea of realising a function without the Aristotelian/scholastic notion of intrinsic final ends.

The faculties involved in perceptual cognition – the 'external' sense organs, the common sense, the memory, and the imagination – had traditionally been construed in corporeal terms, with a good deal of attention having been given to localisation of faculties in the brain by physiologists. But the construal of some level of cognitive functioning in corporeal terms had been associated with various attempts to render matter itself sentient, by invoking the idea of a 'sensitive soul' regulating the corporeal processes from inside. To the extent that he is concerned to show that organic processes, including some cognitive operations, can be construed wholly mechanistically, Descartes has to make sure that his account is compatible with the inertness of matter. His aim is to show that the structure and behaviour of bodies are to be explained in the same way that we explain the structure and behaviour of machines; in doing this he wants to show how a form of genuine cognition occurs in animals and that this can be captured in mechanistic terms. He does not want to show that cognition does not occur at all, that *instead of* a cognitive process we have a merely mechanical one. The aim is to explain animal cognition, not explain it away.

Take the case of visual cognition. We can distinguish between mere response to a visual stimulus, in which the parts of the automaton simply react in a fixed way; visual awareness, in which the perceiver has a mental representation of the object or state of affairs that caused the visual stimulus in the first place; and perceptual judgement, the power to reflect on and make a judgement about (e.g. a judgement as to the veridicality of) this representation. Descartes clearly restricts the last to human beings – it requires the possession of a mind/rational soul. Which of the first two are we to attribute to animals on Descartes' account? The automaton could react directly to the corpuscular action that makes up light without actually *seeing* anything, as a genuine machine might, but this is not how Descartes describes the visual process in automata in *L'Homme*. He tells us, for example, that the

> figures traced in the spirits on the [pineal] gland, where the seat of imagination and common sense is, should be taken to be ideas, that is, to be the forms or images that the rational soul will consider directly when, being united to this machine, it will imagine or will sense any object.[22]

This indicates that there are representations on the pineal gland of the automaton. It is in fact difficult to see how automata could not have 'mental' representations if we are to talk about visual cognition. And it makes no sense to talk about them having representations but not being aware of the content of these representations. Moreover, Descartes certainly does not deny states such as memory to animals, and remembering something is just about the paradigm case of grasping the content of a representation.

The problem is that, while Descartes can allow that automata have representations, it is not immediately clear how he can allow that they grasp the content of these representations if they are not aware of them as representations: if, unlike human beings, they cannot make judgements about them as representations, e.g. about their veridicality.

In what sense can automata be aware of the content of representations without being able to respond to them as representations? Descartes' problem might be put in these terms. The behaviour of automata is such that they must be construed as responding to perceptual and other cognitive stimuli in a genuinely cognitive way, that is, in a way that simply goes beyond a stimulus-response arc. In other words, their behaviour indicates that they are sentient. But they are not conscious, that is, they have no awareness of their own cognitive states as such and so cannot make judgements as to their content. Consequently, Descartes has to account for the behaviour of sentient but non-conscious automata. Because automata are literally 'mindless', this can only be done in terms of a mechanistic physiology.

What we need to do is to capture the difference between sentient and non-sentient behaviour, and set out how this is reflected in differences at the level of a mechanistic physiology. My account of Descartes on this issue is largely a reconstruction of what kind of response was available to him on the basis of some very inconclusive remarks that he makes, but I believe that it does represent a strategy that is consonant with his general approach.

On the first question, the difference between sentience and non-sentience, is of course a grey area, but one crucial difference that we might point to is that there is a sense in which sentient beings are able to process information; they are able to interpret stumuli, and this interpretation determines their response. Descartes gives us some hints as to how this difference might be manifested in Chapter 1 of *Le Monde*, for not only is it established there that there is a certain level of processing of visual information that requires nothing over and above corporeal organs, but we are also given some account of what such processing would consist in.

In Chapter 1 of *Le Monde*, Descartes looks at the relation between the physical agitation of matter that results in a stimulation of the eye, and the visual cognition that we have as a result of this. Previously, his account had focused on getting the 'perceptual' part of perceptual cognition right, whereas here he concentrates on the 'cognition' side of the question. The account of cognition in the *Regulae*, for example, is little more than a mechanist reworking of medieval faculty psychology: the perceptual process involves stimulation of the external sense organ, which in turn conveys motions or 'agitations' to the common sense, and then to the memory, and finally to the imagination. The account presented in the first chapter of *Le Monde* is different from this. Perceptual cognition is not thought of in causal terms, and it is not thought of as a multi-stage process. Rather, the treatment focuses on the question of how we are able to respond to certain properties or events as information.

In the first chapter of *Le Monde* Descartes suggests that we conceive of visual cognition, not in terms of the mechanical-causal process involved in perception, but in terms of a single unified act of comprehension. He spells this out in terms of a new linguistic model of perception:

> Words, as you well know, bear no resemblance to the things they signify, and yet they make us think of these things, frequently even without our paying attention to the sound of the words or to their syllables. Thus it may happen that we hear an utterance whose meaning we understand perfectly well, but afterwards we cannot say in what language it was spoken. Now if words, which signify nothing except by human convention, suffice to make us think of things to which they bear no resemblance, then why should nature not also have established some sign which would make us have the sensation of light, even if the sign contained nothing in itself which is similar to this sensation? Is it not thus that nature has established laughter and tears, to make us read joy and sadness on the faces of men?[23]

If we distinguish between the question of how perceptual information is conveyed, and the question of how perceptual information is represented, then we can see that Descartes is retaining a causal-mechanical model for the first, and advocating a linguistic model for the second. On the linguistic model, we grasp an idea in virtue of a sign which represents that idea to us. So, in the case of a conventional linguistic sign, when we know English, the word 'dog' conveys to us the idea of a dog. And just as conventional signs do not resemble what they signify, so too natural signs do not resemble what they signify either. Descartes tells us that there is in nature a sign which is responsible for our sensation of light, but which is not itself light, and which does not resemble light. All there is in nature is motion. In the case of a natural sign like motion, provided we have the ability to recognise and interpret it, when we grasp motion what it will convey to us is light. Light is what we will experience when we respond in the appropriate way to the sign. As examples of natural signs, Descartes tells us that tears are a natural sign of sadness and laughter a natural sign of joy. One of the things that distinguishes signs from causes is that whether a sign signifies something to us – that is, whether we can call it a sign in the first place – depends on our ability to recognise and interpret the sign, and it is this ability on our part that makes the signs what they are. Causation is clearly different from this, for causes do not depend in any way upon our ability to recognise them. The question is what makes natural signs *signs*. It cannot be, or cannot merely be, something in nature, for something cannot be a sign for us unless we can recognise it, so it must be something in us that makes tears, or laughter, or a particular kind of motion, signs. This something in us must be an acquired or an innate capacity; and Descartes' view is that it is an innate capacity which, it will turn out, God has provided us with. There would be no natural signs unless we had the capacity to recognise them as such.

Here, I suggest we have the two key pieces in the account of sentience. Sentient responses are different from non-sentient responses in that, in the latter case, we can give a full account merely by showing the causal-mechanical processes involved. In the case of sentient responses, this will not tell us everything we need to know, and we need to supplement it with a different kind of account. There is an element of reciprocity in perceptual cognition as linguistically modelled that we do not find in the causal-mechanical account. The linguistic model enables us to grasp what perceptual understanding consists in, whereas the causal-mechanical account describes what physical-cum-physiological processes must occur if this understanding is to take place. This is the core difference between sentience and non-sentience. The next question is whether such a form of interpretation modelled on language is realisable in a mechanistic physiology alone. What is needed over and above the causal-mechanical account that we provide of non-sentient responses? Above all, what we need is some means of forming representations in response to perceptual stimuli, and we need some means of storing and recalling these representations. In one sense, many automata – those to which we are inclined to ascribe some kind of sophistication in perceptual cognition, such as higher mammals – clearly have the physiological means to do this: they have pineal glands, which is where perceptual representations are formed, and they have memories, i.e. corporeal means of storage of representations. Note, in particular, that straightforward stimulus-response behaviour does not involve representation and so does not involve the pineal gland: in Descartes' account of the reflex arc in *L'Homme*, the arc bypasses the pineal gland, travelling instead, in the brain, through what he terms a 'cavity', which is almost certainly one of the cerebral ventricles.[24]

But Descartes needs to say more than this, and it is in his tantilisingly brief account of light in the first chapter of *Le Monde* that he gives his indication of what this 'more' might be. Remember that we are told that light is not the stimulus but the response to the stimulus. The stimulus is a particular kind of motion in the smallest kind of matter which is transmitted via the second matter. Now note also that in order to respond to this particular kind of motion by perceiving light, we have to be able to respond in the right way (this is what makes this a significatory event as well as a causal one). To be able to respond in the right way, we need some kind of innate or built-in capacity. Here the question arises whether such innate capacities are part of our corporeal organs or our minds. One only has to note the fact that automata are able to see, that is, perceive light, whereas disembodied minds are not, to recognise that the capacity to grasp various kinds of translational and rotary motion as light must naturally reside in corporeal organs. Descartes never suggests that automata cannot respond to natural signs; indeed, such functions as nutrition in higher animals, where the appropriate kind of food has to be sought out visually or olfactorily, clearly require such recognitional capacities. Indeed, more generally, it is difficult to explain how animal instincts are to be accounted for if not in terms of some innate capacity.

In more modern terms, what we need is 'hard wiring'. The brain needs to be fitted out so as to respond in the appropriate way. The hard wiring makes sure you get the right kind of representations: that you see light, that is, have a visual image which displays shapes and perhaps colours, when stimulated in the requisite way. It is not something in nature that causes us to have visual images, it is a combination of a stimulation produced by nature and certain features of an animal's physiology which result in a particular kind of representation, a visual perception.

This is clearly different from what happens when an act of perceptual judgement is made, but is it so different from what happens when, say, a plant bends towards the light, or the foetus develops into a fully formed member of the species, which are similar kinds of process on Descartes' account?

I think the difference might be characterised in this way. In the case of embryology, Descartes effectively denies that a functional understanding of the development of the foetus (e.g. one that says that the foetus develops in the way it does so that it can become an adult of the species) tells us anything at all, and he replaces it with a mechanical-causal story. In the case of perceptual cognition in automata, he does not deny that there is a functional story to be told, but rather indicates how the functional story can be translated into the terms of a mechanistic physiology without losing the key insight that perception of *x* by *y* involves *x meaning something to y*, so that, for example, *y* perceives *x* as a lion. What is needed is the capacity to translate the visual stimulation, which might be characterised as agitation of the corpuscles making up the retina, into the requisite perceptual representation, that is, one that conveys the idea of a lion. This can be achieved by the requisite corporeal organs in the brain.

Conclusion

I said above, in discussing Descartes' embryology, that Descartes is not denying that there is question as to why its constituent matter behaves in such a way that the foetus develops into an adult of a particular species. What he is saying is that the explanation for that is not something *internal* to the development of the foetus but *external* to it. God made it so, and God is the only final cause. What Descartes is concerned with are internal causes. The same holds for his account of perceptual cognition. Descartes does not deny that God has given automata the sense organs they have so that they might sustain themselves in the world. It is just that the question of *how* the sense organs operate, which is what he is concerned with, is different from *why* they operate in that way: indeed, on Descartes' account, these are *completely* different questions.

However, when the body is considered, no longer as the body of an animal or an *homme machine*, but as part of what Descartes will refer to as 'the substantial union of mind and body',[25] intrinsic goals re-enter the picture. Human beings are able to reflect upon and make judgements about the content of their perceptual representations, and the nature of perception is transformed as a result. Unlike the perceptual cognition of an automaton, which has no intrinsic goals, human perception must be considered in terms of a goal, the goal of understanding the world, and it can be criticised, for example, to the extent to which it fails to achieve that goal. Intrinsic goals enter the picture because of the presence of a conscious intelligence, and that, on Descartes' account, is their proper place.[26]

Notes

1 See ch. 3 in this volume.
2 I can only mention what seems to me the right interpretation here: a detailed defence is given in my *Descartes: An Intellectual Biography* (Oxford, 1995).
3 See, for example, chs. 2 and 3 of *Le Monde* (AT x. 7–17).
4 See, in particular, *Les Passions de l'âme*, AT xi. 301–488, and the two letters to Regius of May 1641, AT iii. 369–70, 371–5.
5 AT vii. 413–4.
6 J. Cottingham, 'A Brute to the Brutes?', *Philosophy* vol. 53 (1978), 551–9: 553.
7 AT xi. 120.
8 Engravings of a number of these hydraulic devices appeared in Salomon de Caus, *Les raisons des forces mouvantes avec diverses machines tant utiles que plaisantes ausquelles sont adjoints plusioeurs desseigns de grotes et fontaines* (Frankfurt, 1615), with which Descartes was familiar.
9 AT vi. 50 and 59. The analogy is repeated at the end of article 16 of *Les Passions de l'âme*. It also appears at the beginning and end of *Le Monde*.
10 Descartes' distance from accounts that envisage mechanism in terms of clockwork is manifest not only in his conception of the materials that convey the mechanistic action, but also in his appeals to the distinctive properties of the different sizes of matter. This is evident not only in his physical optics – where the three sizes of matter are used to explain the production of light, its transmission, and its refraction or reflection respectively – and in his cosmology – where the three kinds of matter are used to account for the make-up of the sun, the fluid that carries planets around the sun, and the planets themselves – but also in his physiology. A mechanistic model in cardiology might take Harvey's account of the circulation of the blood, in which the heart causes its own movement by muscular expansion and contraction, as providing a full account. Descartes, in *L'Homme* and in a more elaborate way in the *Description du corps humain*, sees the circulation of the blood as requiring a cause for its motion and, rejecting Harvey's vitalistically conceived idea that the cause of the

pumping is simply vital forces in the organism, argues that the circulation must be explained by the ebullition of the blood, that is, by thermogenetic processes which take us down two levels from the gross matter making up the organs to the finest matter which he has shown in *Le Monde* to provide a better explanation of combustion than the postulation of an element of fire.

11 See ch. 8, above.
12 AT xi. 245–52.
13 AT xi. 247.
14 AT xi. 249–50.
15 AT xi. 251.
16 AT xi. 252.
17 AT xi. 253.
18 AT xi. 254.
19 AT xi. 254.
20 AT xi. 274–5.
21 See my discussion in the Introduction to my translation of Arnauld's *On True and False Ideas* (Manchester, 1990).
22 AT xi. 176.
23 AT xi. 4.
24 AT xi. 142.
25 On this doctrine, see my *Descartes, An Intellectual Biography*, op. cit., 388–94.
26 Research for this chapter was supported by a grant from the Australian Research Council. I am grateful to Peter Anstey, Annie Bitbol-Hespériès, and John Sutton for comments, and to Margaret Wilson for comments on an earlier version. I presented earlier versions at the Sorbonne, Oxford, Eötvös University (Budapest), Federal University of Rio de Janeiro, Hong Kong University, and the University of Helsinki, and I am grateful to audiences for advice and comments.

17 *Bêtes-machines*

Katherine Morris

Descartes' '*bête-machine'* doctrine is commonly, and, I will argue, wrongly, glossed in characteristic ways.[1] First, the gloss that many Anglophone philosophers routinely put upon the *content* of this doctrine is that non-human animals are *unconscious*, a claim which they understand as meaning that animals neither think nor feel. To put it baldly, I will argue that in Descartes' view, animals could feel but not think. Second, the *bête-machine* doctrine is commonly viewed as a scientific hypothesis, one that is in principle open to empirical refutation. I will argue that for Descartes it was clearly a metaphysical, not an empirical, doctrine. Third, although it is sometimes recognised that he claimed 'moral certainty' for this doctrine, that concept is not well understood in the literature, hence neither are Descartes' argumentative strategies vis-à-vis the doctrine.

Twentieth-century Anglophone misunderstandings of the doctrine are, I think, the result of a complex combination of factors:[2] changes in many of the central concepts (e.g. 'thinking' and 'consciousness'), together with a reluctance to explore or even acknowledge such changes; a general ambience of empiricism which stands in the way of recognising or properly treating claims put forward as metaphysical truths; and a widespread leaning toward a kind of division of philosophical labour which tries to divorce philosophy of mind from theology, ethics, and metaphysics. Nowhere do these broad alterations in the climate of philosophising show up more clearly than in twentieth-century treatments of the *bête-machine* doctrine.

The content of the *bête-machine* doctrine

Practically the first thing you learn in 'Descartes for Beginners' is that Descartes held that '[m]an is the *only* conscious animal; all other animals . . . are merely complicated, but unconscious, machines'.[3] Non-human animals, in short, neither think nor feel.

I want to begin by challenging this interpretation of the content of Descartes' *bête-machine* doctrine.[4] It is important to recognise from the start that he has *two* distinct targets, which require quite different sets of arguments. One is the Aristotelian doctrine that animals have a non-mechanical 'principle of movement and life', viz. sensitive souls. Against this doctrine, Descartes argued that there is no need for such non-mechanical principles, since sentience is mechanically explicable. (Far from challenging the supposition that animals are sentient, this line of argument *presupposes* it.) The other target of his arguments is the post-Montaignean view that animals *think*, i.e. have *rational* souls. It should be clear that this *is* a distinct target, since the neo-Aristotelians would certainly deny that animals have rational souls (and hence deny that they think). It should also be clear that these two targets will require very different arguments; Descartes may be able to use Ockham's razor to do away with sensitive souls, but he certainly cannot do that with rational souls! Moreover, undermining these two targets will be important to him for different reasons. The one is important to the construction of a mechanics-based natural science; the other has more direct moral and theological ramifications (e.g. that killing a pig to eat amounts to murder, that pet dogs should be baptised, etc.).

To put it in a nutshell, many twentieth-century Anglophone critics of the *bête-machine* doctrine elide the distinction between sentience (traditionally ascribed to the sensitive soul) and rationality (ascribed on all hands to the rational soul) by their use of the term 'consciousness', and hence elide the crucial distinction between these two targets of his arguments.

Descartes' claim is that while beasts feel, they do not think. I will look briefly at each of the two halves of this more closely, and in so doing will explore some of the reasons why the doctrine is so commonly misinterpreted.

Sentience

In Descartes' view sentience is mechanically explicable. Thus the *bête-machine* doctrine does *not* imply that animals lack sentience; on the contrary, animals are paradigms of sentience: they are sentient machines. There are numerous passages that demonstrate that he held animals to be capable of feeling hunger and anger (e.g. 'all animals easily communicate to us, by voice or bodily movement, their natural impulses of anger, fear, hunger, and so on'[5]). But Descartes aimed to *extend* the range of application of *mechanical* explanation beyond its then-accepted range. *L'Homme* explicitly set out to demonstrate that all of the functions which were traditionally taken to require a vegetative or sensitive soul could be performed by an 'organic machine'. He drew the conclusion: 'In order to explain these functions . . . it is not necessary to conceive of this machine as having any vegetative or sensitive soul or other principle of movement and life, apart from its blood and its [animal] spirits.'[6] Thus his aim was to explain *sentience* without recourse to a sensitive *soul*. Success in doing so, if combined with Ockham's razor, would imply that animals did *not* have 'any vegetative or sensitive soul'. (Note here that Ockham's razor has shifted in its significance; it was understood, not as a *heuristic* injunction against multiplying *entities* beyond necessity, but as a law, deducible from the simplicity of *God's* operation, according to which God would not multiply 'principles' beyond necessity. Hence, to show that animal behaviour could be explained 'on mechanical principles' is to show that there is no need for other '*principles* of movement and life' in explaining their behaviour.)

There are good reasons why this line of argument should be hard to perceive today. One is a widespread shift in the concept of sentience. Critics today like to latch onto Nagel's expression 'what's it like?' as capturing something important about 'the' concept of sentience; so they will complain that, on Descartes' view, there is 'nothing that it's "like" to be, say . . . a seriously injured dog (let alone a bat)'.[7] But, to put it baldly, this 'what's it like?' had no part whatsoever in the seventeenth-century conception of sentience.[8] Rather, the conception was linked to responsiveness to stimuli, particularly those signalling benefits and dangers, hence closely bound up with welfare.[9]

As a consequence of this change in the concept of sentience, we today are likely to find it puzzling that Descartes should identify 'ignorance of anatomy and mechanics'[10] as an important source of his contemporaries' resistance to the idea that machines lacking vegetative or sensitive souls could be sentient. (He combated this ignorance by explaining the details of anatomy and the actual functioning of man-made machines.) Our puzzlement should disappear if we see what *they* understood by 'sentience'. They found it very difficult to imagine that a machine could be internally complex enough to respond as sensitively to features of their environment as animals evidently do: as Arnauld observed,

> at first sight it seems incredible that it can come about, without the assistance of any soul, that the light reflected from the body of a wolf onto the eyes of a sheep should move the minute fibres of the optic nerves, and that on reaching the brain this motion should spread the animal spirits throughout the nerves in the manner necessary to precipitate the sheep's flight.[11]

Such incredulity could plausibly be dispelled by a better appreciation of anatomy and mechanics.

A second reason why this line of argument is hard to grasp is a concomitant shift in the concept of consciousness. We today tend to consider it a tautology that whatever is sentient is conscious. If 'consciousness' is supposed to be what translates Descartes' word '*conscientia*', this is definitely not the view either of Descartes or of his neo-Aristotelian contemporaries. *Conscientia* was for them the power of the rational soul to reflect on its thoughts. Since they held that animals were sentient but lacked rational souls, there was certainly no implication from 'sentient' to 'conscious'.

So, against the neo-Aristotelians, Descartes argued that sentience (as they understood it, *not* as we understand it) could be fully explained mechanistically, with no need for a sensitive soul. I will say nothing more about this target of Descartes' argument; the other is a trickier one to tackle.

Thinking

Descartes' second target was the post-Montaignean view that animals could think and hence had rational souls. We will look in later sections at his arguments in this area. Here I want to investigate some of the intellectual obstacles that stand in the way of our understanding the content of this aspect of the *bête-machine* doctrine.

One huge obstacle to *our* understanding him is failure to see what he built into the concept of 'thought'. Thinking is in his framework inseparable from the capacity to make and refrain from making judgements, and judging (likewise refraining from judging) is an operation of the free will.[12] Descartes held the attractive view that there is an opposition between mechanical explicability and free will. This is clearly implied in this passage, which also, importantly, links freedom with moral agency and responsibility: 'The supreme perfection of man is that he acts freely or voluntarily, and it is this which makes him deserve praise or blame.'[13] Thus, for Descartes, the concept of thinking was internally related to the concept of moral responsibility. This should hardly be surprising, given that the rational soul was supposed to be immortal and its moral character to be assessed on the Day of Judgement, but it is not commonly noted in twentieth-century Anglophone commentaries.

This is directly connected to Descartes' tying the concept of 'thought' tightly to the concept of 'consciousness', e.g. in the following passage: 'By the term "thought" [*cogitatio*], I understand everything which we are aware [*nobis consciis*] of as happening within us, in so far as we have awareness [*conscientia*] of it.'[14] This is widely noted, but not widely understood in the twentieth century. One reason might be changes in the concept of consciousness already noted. Another might be unfamiliarity with the scholastic conception of *conscientia*, which included (the etymologically linked) *conscience*, the power of the rational soul to reflect on its own moral actions and character.

A consequence of this is that in denying that animals could think, Descartes was, *inter alia*, denying that they had free will in any sense that implied moral responsibility.[15] It follows that they cannot be praised or blamed for what they do: it makes no sense to 'praise automata for accurately producing all the movements they were designed to perform, because the production of these movements occurs necessarily'.[16] To deny rational souls and hence moral agency to animals is to deny that they possess the power of *conscientia*. But it would be seriously misleading to twentieth-century readers (because 'consciousness' no longer means to us what it did to him) to gloss *this* as saying that in that case beasts are *unconscious*;[17] it might be better to say that they are 'conscienceless'.

The concepts of 'thought', 'freedom', '*conscientia*', 'possession of a rational soul' and 'moral responsibility' are wound up together in Descartes' reasoning. At this point, it might be expected that most people, both then and today, would surrender their opposition to *his* claim that animals do not think. After all, when I say 'My cat thinks that the wriggling string is a mouse's tail', I do not suppose that she has culpably failed to restrict her infinite will to the scope of her finite intellect; if she bites the hand that feeds her, I do not ascribe to her a defective moral character, and so on. So surely I should simply say 'Very well, if that's what you mean by "thinking" then animals don't think', and the argument would be over before it began.

This expectation would, of course, be wholly naive. We philosophers will fight for the right to use the word 'thinking' in our own (as we would say, the *right*) way. (As Descartes would put it, the prejudices of youth die hard.)[18] Descartes certainly fought for his conception of 'thought' (or, as he would put it, fought against misunderstandings of what thought really is). These 'misunderstandings', he held, rested in part on a widespread confusion, originating in childhood when the mind was immersed in the senses, between what belonged to the mind and what belonged to the body. Expressions referring to functions attributed to the sensitive soul ('feeling pain', 'seeing light', 'walking' and so on), he held, exhibited an ambiguity which both arose out of and reinforced this confusion. Such expressions are ambiguous between referring to attributes of bodies (e.g. the stimulation of the eyes by light), which can be possessed by beasts, and attributes of minds (e.g. thinking that one's eyes are being stimulated by light), which cannot.

This confusion between what belonged to the mind and what belonged to the body in his view was so widespread and so dangerous that he expended a great deal of intellectual effort in trying to 'unconfuse' his readers by getting them to disambiguate these expressions. For example, in the *Meditationes*, he distinguished between two senses of 'seeing light', one of which went the way of the body on the hypothesis that the Demon was deceiving him, the other of which (what he there called 'the restricted sense') was a form of thinking.[19] Again, he tackled an ambiguity in the expression 'principles of movement': there are 'those [movements] which are performed in us with the help of the mind' and 'those which depend merely on the flow of the animal spirits and the disposition of the organs'.[20] Confusion between these two distinct things is what leads us to 'imagine' that the first as well as the second 'principle of motion' was to be found in the brutes.

Failure to perceive Descartes' disambiguation strategy is a further important source of the usual understanding of the content of the *bête-machine* doctrine (though that failure itself stands in need of explanation). Commentators have noted, for example, that he denied that animals have sensations or passions 'like us' or 'like ours' (e.g. 'As for brute animals, we are so used to believing that they have feelings *like us* that it is hard to rid ourselves of this opinion.')[21] They may even note that he asserted that he did not 'deny sensation [to animals], *in so far as it depends on a bodily organ*'.[22] Such locutions occur regularly and allude to his strategy of disambiguating expressions designating sensations and passions. But commentators routinely suppose that 'lacking feelings like us' means 'lacking feelings', and that 'having sensation in so far as it depends on a bodily organ' means 'not having sensation'! (So scare-quotes sprout around 'feeling pain' and 'seeing light' as they are applied to animals when commentators describe Descartes' position.)[23] Hence the standard gloss on the *bête-machine* doctrine partially arises from commentators' 're-confusing' just what Descartes was at such pains to 'unconfuse'.[24]

Of course, accusations of equivocation are rarely philosophically innocent. To disambiguate is to carve articulations in concepts where you (perhaps from philosophical motives) think they belong. So such 'disambiguations' could be seen as opening Descartes up to the charge of *petitio principii*. (We of course would be equally open to such charges if we tried to show that he had got the concept 'wrong'.) The point remains that in order to understand what it was that Descartes was denying when he denied thought to animals, it is necessary to see what *he* meant by 'thought'. And it must be borne in mind that it is still *open* to someone to *accept* his conception of 'thought' and maintain that animals do think.

The metaphysical status of the *bête-machine* doctrine

It is sometimes suggested that Descartes simply bumbled into the *bête-machine* doctrine through confusion: having correctly noted that animals are not self-conscious, the benighted man was moved to deny that they were conscious.[25] This view (quite apart from presupposing the standard view about the content of the Doctrine) is neither plausible, nor compatible with treating Descartes with the respect due to a great thinker, who manifestly thought a great deal about this issue and considered it to be of immense importance. Wrong he may be, but not through carelessness!

But those who do take the Doctrine seriously, recognising that Descartes thought about it carefully and had reasons for adhering to it, nonetheless often manifest an important misunderstanding of the *status* of Descartes' doctrine; in effect they treat a metaphysical doctrine as an empirical one. In particular, they take Descartes' advocacy of the *bête-machine* doctrine to rest on the following line of reasoning: 'That there are minds or souls attached to some bodies is simply a hypothesis, introduced to account for certain observed facts',[26] and none of the behaviour exhibited by brutes requires such a postulation.

Support for such an interpretation might be sought in a well-known passage from the *Discours* in which Descartes noted that if there were machines which

> bore a resemblance to our bodies and imitated our actions as closely as is morally possible,[27] we should still have two very certain means of recognizing that they were not real men. The first is that they could never use words, or put together other signs, as we do in order to declare our thoughts to others. . . . Secondly, even though such machines might do some things as well as we do them, or perhaps even better, they would inevitably fail in others, which would reveal that they were acting not through understanding but only from the disposition of their organs.[28]

But before asking (in Section III) what this passage *is* doing, I want to make a claim about what it *cannot* be doing. Descartes' claim here *cannot* be that some behavioural phenomena require the postulation of minds or rational souls to account for it, and that in the absence of these behavioural phenomena there is no necessity to posit reason or understanding.

The reason for this is that within Descartes' framework possession or non-possession of a rational soul is part of something's *nature* or *essence*.[29] The nature of a creature is not something to be empirically determined; it is at two removes from its observable 'behaviour'. First, natures are connected to powers or faculties, and the link between faculties and observable behaviour is not straightforward; and second, natures attach to *species*, and the link between natures and the observable behaviour of *individuals* is *a fortiori* not straightforward.

Let us look first at the connection between possession of a faculty and observable behaviour. The rational soul has the faculty of thinking. How do you establish whether an individual has this faculty? On the one hand, the faculty of thinking is exercised, *inter alia*, in speech: if something can speak, then it can think, hence has a rational soul. Moreover, if something *cannot* speak or otherwise express its thoughts, then it *cannot* think.[30] To have the faculty of thinking and to have the power of expressing thoughts is one and the same thing. But how do you determine whether something can speak? That it utters words is clearly insufficient to establish that it can speak; parrots utter words, so too does Descartes' man-shaped machine ('if you touch it in one spot it asks what you want of it, if you touch it in another it cries out that you are hurting it'), but in neither case do their utterances count as speech. That it is capable of giving 'appropriately meaningful answers to what is said in its presence', even in a wide variety of circumstances, does not *demonstrate* that it is capable of speaking; the chance remains that in as-yet-untested circumstances it will fall down.

(Similar remarks apply to other exercises of the power of thinking, e.g. intelligent response to 'the contingencies of life'.) And on the other hand, that something *does* not utter words, while it may entail that it *does* not speak, does not entail that it *cannot* speak, hence does not entail that it cannot think. That it does not respond intelligently to 'the contingencies of life' does not show that it cannot do so: there remains, for example, the possibility that it is a human being who, for reasons of his or her own, is simply pretending to be incapable of answering appropriately or pretending to be stupid.

These difficulties are exacerbated by the fact that natures (hence faculties) belong to species, not to individuals. So, on the one hand, if it is *known* that the individual belongs to a species whose nature does not include possession of a rational soul, then no matter how apparently intelligently the individual responds to the contingencies of life, no matter how seemingly appropriate its utterances are to a wide variety of circumstances, the individual is not exhibiting intelligent behaviour and it is not speaking. This is important, because something's lacking a rational soul (as machines do, by definition) does *not* make it 'absolutely impossible' for it to behave in as complex a way as human beings do. (See Section III on the term 'absolutely impossible'.) It cannot be absolutely impossible for a machine to pass the 'Turing test'. There can be no a priori limit to the complexity of a machine which could be created by God, hence it is not absolutely impossible for God to make a machine behaviourally indistinguishable from a human being. But *given* that it is a machine, even if it were to pass Descartes' two tests, it *could not* be exhibiting the power of thinking.

And on the other hand, if it is *known* that an individual *does* belong to a species which by nature has a rational soul, then no matter how apparently witless its performance, no matter how entirely inarticulate it may be, the individual does have the faculty of thinking and hence possesses a rational soul. This is vital, since infants clearly do not exhibit the 'behavioural phenomena' referred to in the above passage. But we do not on those grounds deny that they have rational souls. On the contrary, we can 'see' that they are 'of the same nature as adults',[31] from which it follows that they have the power of thinking and so have rational souls.

Thus there *cannot* be any straightforward inference from the fact that something behaves in a certain way to the conclusion that it has a rational soul; nor can there be any straightforward inference from the fact that something does not behave in a certain way to the conclusion that it lacks a rational soul. Talk of 'postulating' or 'hypothesising' rational souls in order to 'account for' certain 'observed facts' or 'behavioural phenomena' seems to locate the possession or non-possession of a rational soul in the realm of discourse appropriate to the empirical investigation of individual creatures. It definitely does not belong there. That something has or lacks a rational soul concerns its *nature* (i.e. the nature of the *species* to which it belongs), hence is a metaphysical and not an empirical fact, and truths about natures (i.e. essences) are neither demonstrable nor refutable by empirical means.[32]

Thus the *bête-machine* doctrine – the claim that animals lack rational souls – is not to be settled conclusively by observation of the behaviour of individual animals. *Can* it be 'settled conclusively' in Descartes' view, and if so how?

The certainty of the *bête-machine* doctrine

There is what could look like a tension in Descartes' attitude toward this. In places he claimed to be able to prove that animals could not think; elsewhere he expressed an apparently softer position, claiming only that we cannot prove that they do think. Sometimes he is charged with being confused on this point;[33] sometimes he is said to have altered his position over time;[34] sometimes one or the other claim is downplayed so as to reduce the tension.[35]

I want to resist all three of these reactions. As for the first, I am, once again, reluctant to charge him with confusion on a point which he considered at such length. Second, the evidence for modification over time is, I believe, inadequate.[36] Third, there are too many expressions of each type of attitude to make downplaying either one of them a satisfactory tactic. I want to claim that this appearance of tension can be dissolved if we recognise that it is Descartes' view that it is 'morally certain', but not 'absolutely certain', that non-human animals lack rational souls. But to understand this, we need both to understand what these technical terms mean, and to see what Descartes' strategy is in the passage from the *Discours* quoted earlier.

Although his terminology is not wholly clear on this point, the concept of moral certainty (moral necessity) is in Descartes' framework contrasted with both 'absolute' and 'metaphysical' certainty (or necessity). (Likewise, *mutatis mutandis,* for moral, metaphysical and absolute impossibility.) Roughly speaking, what is metaphysically certain cannot be called into doubt under any hypothesis. (Axioms or 'common notions', such as 'Nothing comes from nothing' fall into this category.) What is absolutely certain can be called into doubt only by a 'very slight and "metaphysical" ' reason for doubt, viz. the hypothesis that God does not exist or is a deceiver. (Truths about essences which are clearly and distinctly perceived (e.g. arithmetical truths) fall into this category.) Finally, what is morally certain is 'beyond all *reasonable* doubt' (it can be called into doubt only by an 'absolute' reason for doubt) and involves principles backed up by God's justice. This last concept will require further explication.

The terminology of moral necessity (or certainty) and moral impossibility was common coinage of the scholastics; most of their paradigms of moral certainty concerned testimony (and of course much of their concern here was with miracles):

> . . . the things that we know from the constant testimony of so many people that it is morally impossible that they could have conspired to assure us of the same thing if it were not true. For example, people naturally have some trouble conceiving that there are antipodes. However, even though we have never been there, and thus we know nothing about them except by human faith, we would have to be insane ['lost all sense'] not to believe in them.[37]

Although it is clearly 'absolutely possible' that a massive conspiracy could have been organised to persuade us that the antipodes exist, it is nonetheless 'morally impossible'. So the existence of the antipodes, given the testimony, can be said to be morally certain; indeed 'we ought to consider [the judgement that the antipodes exist] as certain and as indubitable as if we had mathematical demonstrations of [it]'[38] (i.e. to consider it *as* 'absolutely certain'). In other words, it would be 'insane' not to believe in the antipodes given the testimony we in fact have.

'Insanity' (*dementia*) is contrasted with '*le bon sens*', or '(practical) reason', 'the [God-given][39] power of judging well'.[40] (It is clear therefore that we cannot read the term 'insanity' as indicating an illness; insanity in the relevant sense is a moral defect. There are comparable uses in English today.) The thought appears to be this: if you use this power to the best of your ability in everyday moral and civil life, if you stake your moral life on what it would be insane not to believe and *treat* such beliefs *as* 'absolutely certain', then you can be assured of salvation come the Day of Judgement.

'Morally certain' might be expressed in terms of 'beyond all reasonable doubt'. Note, however, that that is to be distinguished from 'highly probable' (as 'morally certain' is commonly understood),[41] for two reasons: first, because 'reasonable' is a moral term ('in conformity with God-given "good sense" ', 'responsible'); and second (relatedly) because, unlike the case with 'high probability', there is in any given situation a more-or-less definite stopping-point for investigation: you may have a duty to investigate some things, e.g. the character of the witnesses if unknown to you, but once you have done that you have got moral certainty. It is these moral aspects that connect moral certainty to certainty of salvation, and hence what makes the term 'moral' appropriate.

What is less clear is why moral certainty is *certain*. The difficulty is that it looks as though 'morally certain' does not *entail* 'true'.[42] The most it entails is that your reliance on such beliefs will not stand in the way of your salvation. The phrase 'beyond all reasonable doubt' has its home in courtrooms; even highly responsible juries may end up with incorrect verdicts, because of the unavailability of crucial evidence; e.g. a witness whose character they had investigated as thoroughly as could reasonably be expected turns out to have been lying.[43]

We might, however, find a solution to this difficulty in the fact that 'good sense', like reason in general, must operate on 'principles', in particular, perhaps, principles like 'Constant testimony is trustworthy'. While God is not in the business of guaranteeing that even the best use of good sense necessarily yields truth, what he does do is ensure that the principles on which good sense operates tend towards the truth. One might even make sense of this by suggesting that if it were otherwise, moral life would be impossible: God's creatures would be expected to adhere to the moral law, but this expectation would be impossible to fulfil. This sounds like an accusation of injustice. But as God is not unjust, the principles on which good sense operates must tend towards the truth. This might help to give some content to the idea that moral certainty can appropriately be called 'certainty'.

Let us now go back to the passage from the *Discours*. The claim here is that 'it is *morally impossible* for a machine to have enough different organs to make it act in all the contingencies of life, in the way in which our reason makes us act'.[44] This is premissed on the claim that a machine's 'organs need some particular disposition for each particular action'.[45] The point is surely this: given any 'contingency of life' that we encounter, our reason makes us act in it in an intelligent manner; likewise, given any question put to us, our reason makes us respond in an 'appropriately meaningful way'. The designer of the machine would have had to anticipate *every* contingency of life that the machine would encounter, and *every* question that would be put to it, in order to design in enough organs to make it act as our reason makes us act. Of course God, being omniscient as well as omnipotent, could do this; it is absolutely possible. And of course he would not, because it would make moral life impossible. But that is not the point here. (Descartes doesn't seem to be relying *here* on the fact that *only* God could have made such a wonderful machine.) Instead we should be struck by the analogy between such an elaborately constructed machine and the idea of an elaborately orchestrated conspiracy to persuade us of the existence of the antipodes; it would be equally insane to believe that either of these things had occurred. The principle of *le bon sens* here (parallel to the principle that constant testimony is trustworthy) might be that whatever to *all* appearances expresses a power possesses it. (One can easily see that moral life would be impossible if this principle did not tend toward the truth.)

But how exactly is this supposed to provide us with 'very certain means' of telling an *homme-machine* from a real man? We might be able to work out (to the level of moral certainty) that something was *not* a machine by the fact that it *passed* the tests,[46] but it does not at all follow that something's *failing* the tests makes it morally certain that it *is* a machine. As we have already suggested, some 'real men' might, for example, deliberately set out to fail them;[47] moreover, all human infants fail them as well.

But perhaps we are misunderstanding the purpose of these 'tests'. (Perhaps 'tests' is a misleading way of understanding the phrase 'means of recognising'). The whole trajectory of the argument is *from* the fact that these are machines *to* their morally certainly *failing* the two tests, not the other way around. They are not tests for working out *whether* what you are faced with is an *homme-machine* or a 'real man'. It is *given* that they are machines, hence we already know what their nature is (viz. they lack a rational soul and so all their actions depend on the disposition of their organs); their morally certainly failing the two tests is inferred from this knowledge of their nature.

What then of animals? Here we cannot begin from a knowledge of their nature; so how exactly has this consideration of machines helped us? We cannot argue that since animals fail the two tests they must lack rational souls, since having or lacking a rational soul is not empirically determinable. We cannot even argue on the basis of the preceding paragraph that since they fail the two tests, it is morally certain that they lack rational souls, since the implication there goes the other way around. (What lacks a rational soul morally certainly fails the tests.) In the end, perhaps all that the consideration of machines has done is to focus our minds on the right *kinds* of things.[48]

In effect, it seems to me, the main argument in the *Discours* is very simple: the premiss is that beasts *do* not speak (or otherwise express thoughts), and the conclusion is that it is morally certain that beasts *cannot* speak (or otherwise express thoughts). Since anything with a rational soul can think, hence can express thoughts, it is morally certain that beasts lack rational souls.

The premiss, that beasts do not speak, is defended against various objections. The suggestion that parrots *do* speak is in effect rebutted by carefully distinguishing speech from 'the natural movements which express passions'.[49] This argument puts the onus of proof back upon the defender of animal speech to show that animals utter words that are clearly *not* merely the expression of an animal passion.[50] The objection that 'the beasts speak, although we do not understand their language' is rebutted by the suggestion that 'if that were true . . . they could make themselves understood by us as well as by their fellows'.[51] It is unclear at first sight why this counts as a rebuttal. Perhaps (it might be objected) they *could* make themselves understood to us but *do* not. Descartes replies to this objection elsewhere: 'Since dogs and some other animals express their passions to us, they would express their thoughts also if they had any.'[52]. This argument is clearly not irresistible. It remains a possibility that animals might have some reason for expressing their passions but not expressing their thoughts to us; and Montaigne would no doubt try to turn the argument around: we can imagine him ascribing to dogs the thought that 'since human beings express their passions to us, they would express their thoughts also if they had any'![53] Nonetheless it has a certain persuasive force. It is at least reasonable to conclude that animals do not speak, i.e. do not express their thoughts.

The possibility remains that animals have thoughts but do not express them. Someone might try to defend this possibility by suggesting that they do not speak because they lack the necessary organs. The reply is that, on the one hand, magpies and parrots have the necessary organs, while on the other those human beings (the deaf and dumb) who lack the necessary organs nonetheless communicate their thoughts to us.[54]

It remains absolutely possible that animals have thoughts but do not express them; but it is nonetheless morally impossible. This, it seems to me, is the force of Descartes' word 'incredible':[55] even 'superior specimens of the monkey or parrot species' do not speak 'as well as the stupidest child', and this 'would be incredible' 'if their souls were not completely different in nature from ours',[56] i.e. if they had rational souls.[57] Once again, the idea of a creature having thoughts to express but *never* expressing them is as 'insane' as the idea of an orchestrated conspiracy to persuade us of the existence of the antipodes. (Here the principle of good sense might be: there are no totally unexpressed powers, where 'totally' encompasses all members of the species at all levels of development.) So it is morally certain that animals cannot think. Q.E.D.

This argument trades on the morally but not absolutely certain nature of the inference from total absence of expression of thoughts to absence of the power of thinking. Elsewhere Descartes offers arguments that more clearly depend on the idea that natures belong to 'species', not to individuals. There are creatures (e.g. oysters and sponges) which are 'too imperfect' for it to be 'credible' to suppose that they have immortal rational souls, hence that they think.[58] Here too, the word 'credible' plausibly has to do with moral certainty. It is morally certain that oysters and sponges cannot think; it would be 'insane', contrary to *le bon sens*, to suppose that they did. (Surely no-one supposes that we will be condemned on Judgement Day for our having eaten *huîtres*.) But we can see that they are 'of the same nature' as other beasts. (That this is Descartes' argument is indicated by his reasoning thus: 'there is no reason to believe it [that they possess a rational soul] of some animals without believing it of all'; the presupposition seems to be that all non-human animals have the same nature, so that if one lacks a rational soul, they all must.[59]) So it is morally certain that no non-human animals think. Q.E.D.

Hence we may be certain that treating beasts only with the (considerable!) respect due to any of God's creations, rather than with the special respect accorded to moral agents, is morally permissible, i.e. we are not damning our immortal souls in following our 'good sense' and treating them as lacking rational souls. Hence 'my opinion is not so much cruel to animals as indulgent to human beings . . . since it absolves them from the suspicion of *crime* when they eat or kill animals'.[60] The word 'crime' in this passage has moral significance, since only if what you kill has a rational soul are you guilty of murder; but the expression 'absolves them from the suspicion of crime' is also significant: the point is that if you *treat* it as absolutely certain that animals lack rational souls you will not be condemned on Judgement Day.[61]

How does this discussion help to resolve the tension with which this section began? It should now be straightforward. The apparent tension arose from the fact that Descartes seemed sometimes to claim to be able to prove that animals could not think, and at other times only to be unable to prove that they do think. But to say that 'we cannot prove that animals do think' is simply to say that animals do not express their thoughts to us; but *this* is enough to make it morally certain (to 'prove', to the level of moral certainty) that they *have* no thoughts to express. There is no tension here.

From within his framework, the arguments Descartes offers are good ones. On the one hand, if we can agree (and he has said enough to make it reasonable to do so) that animals never express thoughts, we *must* agree that it is morally certain that they *cannot* express thoughts, hence morally certain that they cannot think. On the other, if (as we must surely agree) it is morally certain that oysters and sponges cannot think, and if (more controversially for modern readers) oysters and sponges are of the same nature as dogs and monkeys, then it is likewise morally certain that dogs and monkeys cannot think.

These are arguments that cannot be made intelligible if they are divorced from the whole framework of thinking about natures and powers, and the connections between what is empirically observable and those natures and powers, or if divorced from the theological-cum-moral framework in terms of which the concept of moral certainty was defined. It seems to me that the decisive move in the conjuring-trick which creates the standard Anglophone perception of the *bête-machine* doctrine is precisely to try (perhaps in the name of simplicity) to divorce this doctrine from moral, metaphysical and theological issues.

Notes

1 I am indebted to Anita Avramides and Gordon Baker for a number of stimulating discussions of this paper, and to Peter Harrison for his very helpful comments on an earlier version.

2 The stress in this paper is on the misunderstandings, and the causes for such misunderstandings, of (many) twentieth-century Anglophone philosophers. It should not be inferred that *only* (nor all) twentieth-century Anglophone philosophers misunderstood the doctrine in something like this way. On the one hand, I am making no claims about twentieth-century *non*-Anglophone philosophers; on the other, Descartes' contemporaries and immediate successors may have exhibited parallel misunderstandings – but arguably the causes there were different. To explore those causes would require another paper; but I mention two here. First, a ground for at least *professing* to misunderstand that was operative then and not at all now was the desire to discredit Descartes' philosophy as subversive of the established theological and scientific order; what more effective way of doing so than blithely to torture animals and claim Descartes' ideas as your justification? Second, those (like Malebranche)

seeking a theodicy in respect of animal suffering might be motivated to find in Descartes' system a proof that animals cannot feel pain. (This is a theme which Peter Harrison has explored extensively, e.g. in 'Animal souls, metempsychosis and theodicy in seventeenth-century english thought', *Journal of the History of Philosophy* vol. 31 (1993), 519–44.).

3 Anthony Kenny, 'Descartes for Beginners', in his *The Heritage of Wisdom* (Oxford, 1987), 119. Cf. also Bernard Williams, *Descartes* (Harmondsworth, 1978), 282 ff.; p. 7 of Margaret Dauler Wilson, 'Animal Ideas', *Proceedings and Addresses of the American Philosophical Association,* vol. 69 (1995), 7–25.

4 This article expands and develops arguments presented in embryonic form in Gordon Baker and Katherine J. Morris, *Descartes' Dualism* (Routledge: London, 1996).

5 AT v. 278.

6 AT xi. 202.

7 Wilson, op. cit., 7.

8 Baker and Morris. op. cit., argue that it *could* have no place; insofar as the 'what's it like' is supposed to be (a) mental, (b) a property *of* some mental state, and (c) inarticulate and incommunicable, the very concept is within Descartes' conceptual framework entirely incoherent.

9 I do not mean to offer this as an *analysis* of 'animal sentience'. Stephen Gaukroger, in his *Descartes: An Intellectual Biography* (Oxford, 1995), has a much fuller and richer discussion of what he terms 'animal cognition' which lays emphasis on the mediation of many of these responses by 'representations' in the pineal gland.

10 AT xi. 224.

11 AT vii. 205.

12 Note that the concept of 'freedom' will shift with changes in the concept of 'thought'. For example, Descartes' conception of freedom clearly gives prominence to *rational choice,* whereas many modern conceptions of freedom stress the mere 'possibility of doing otherwise'.

13 *Principia* I, art. 37.

14 *Principia* I, art. 9.

15 'As for animals that lack reason it is obvious that they are not free, since they do not have [the real and] positive power to determine themselves; what they have is a pure negation, namely the power of not being forced or constrained.' (AT iv. 117) Descartes here distinguished two concepts of freedom that are undoubtedly 'commonly confused'.

16 *Principia* I, art. 37.

17 Peter Harrison has recently played this point rather differently ('Descartes on Animals', *Philosophical Quarterly* vol. 42 (1992), 219–27). He argues (224) that on Descartes' view, animals had *unconscious sensations,* noting as I do here that this was and is a source of misunderstanding. By 'consciousness', Harrison means not '*conscientia*' but 'awareness'. His claim is that animals on Descartes' view have sensations but are unaware of their environment. He here refers to Descartes' likening animal actions to 'those of our actions which are not guided by our thought', e.g. when we 'walk or eat without thinking at all about what we are doing' (AT iv. 573). But the term 'awareness' needs further clarification: there must be *some* sense in which Descartes will allow that a cat stalking a mouse – every fibre of its body tense, its ears pointed forward, its eyes following the minutest move on the mouse's part – is *aware* of its environment! Perhaps we need to make some distinctions: arguably the English term 'awareness' exhibits just the sort of ambiguity that in Descartes' view 'feeling pain' and 'seeing light' do. If I walk through the park deep in conversation with a friend, there is a sense in which all I am aware of is the conversation (after all,

if you asked me what was occupying my mind, that would be my answer), but another sense in which I am aware of the turnings in the path (after all, if I were not aware of the turnings then I'd fall into the lake). (Cf. D.C. Dennett's distinction between awareness-1 and awareness-2, ch. 6 of *Content and Consciousness* (London, 1969).) We might then say that animals are, on Descartes' view, aware in the second sense but not in the first.

18 No-one should suppose that contests over contestable concepts are 'merely verbal', i.e. *superficial*. The stakes are high on both sides. There is little doubt that Descartes accorded vast moral significance to his views about animals: 'after the error of those who deny God, . . . there is none that leads weak minds further from the straight path of virtue than that of imagining that the souls of the beasts are of the same nature as ours . . .' (AT vi. 59). But it is also important to see the direction in which the danger lay: he did not think that people would in fact be led to think, mistakenly, that animals had immortal souls like ours; rather, they would be led to think, mistakenly, that *we* had *mortal* souls like the animals', 'hence that after this present life we have nothing to fear or to hope for, any more than flies or ants' (ibid.). Thus it might almost be suggested that it was *more* important for Descartes that people have the 'right' (i.e. his) conception of thinking than that they accept his claim that animals do not think.

19 AT vii. 29; cf. *Principia* I, art. 9.

20 AT vii. 229–32. Compare Antoine Arnauld and Pierre Nicole, *Port-Royal Logic*, I. §xi (English trans.: *Logic or the Art of Thinking* (Cambridge, 1996).).

21 AT iii. 122, italics added; AT ii. 39.

22 AT v. 278; italics added.

23 E.g., 'a sea lion "enjoying" a roll in the surf' (Wilson op. cit., 7).

24 Gaukroger has called attention to the fact that Descartes sometimes used apparently similar ambiguity-indicating locutions in respect of the predicate 'thinks' (op. cit., 454, n. 165). E.g. 'if they [animals] thought *as we do*, they would have an immortal soul like us' (AT iv. 576, italics added). He interprets this locution as indicating an ambiguity in the word 'thought', with the consequence that in one perfectly good sense of the word 'think', animals can in Descartes' view think. Though tempted, I remain unconvinced by this interpretation. Gaukroger interprets the phrase 'as we do' restrictively; but then the construction of this sentence would apparently require that he also interpret the parallel 'like us' (in 'they would have an immortal soul like us') restrictively. This would seem to make the expression 'immortal soul' ambiguous (indicating something possessed by animals in one sense of the phrase). That, I think, cannot be right. (Surely the sense of the sentence is that if animals thought, as we do, they would have immortal souls, as we do.) For present purposes, however, there is no need to resolve this issue. We are in agreement that what is being denied to animals is thought, in the sense that connects it with freedom and moral responsibility.

25 Kenny, op. cit., 9.

26 A.M. MacIver, 'Is There Mind–Body Interaction?', in G. Vesey, ed., *Body and Mind* (London, 1964), 308. Cf. Wilson, op. cit., 8.

27 'Morally impossible' is commonly translated as 'impossible for all practical purposes'; likewise 'morally certain' is translated as 'certain for all practical purposes'. This is liable to be misleading to us today; see the third Section.

28 AT vi. 56–6; cf. AT iv. 573.

29 Wilson talks of 'reason and understanding' here rather than of 'rational souls'. This is part and parcel of her explicitly declared intention (misguided, in my view) to focus 'on issues specifically of cognition and consciousness', at the expense of metaphysical issues (op. cit., 8).

30 There are no doubt thorny issues about how a disembodied soul expresses its thoughts; the entailment remains, however.
31 AT v. 345. Seeing this is something done by the intellect as opposed to the senses, cf. the 'perception' of the nature of the wax in Meditation II.
32 Wilson seems tacitly to suppose that all differences must be empirical differences. She uses the epithet 'bizarre' for Leibniz' view (also, I claim, Descartes' view) 'that an important tenet of his mature metaphysics rules out in principle *any behavioural evidence* for the presence of non-mechanical cognitive states' (op. cit., 18).
33 E.g. Marjorie Grene, *Descartes* (Brighton, 1985), ch. 2.
34 E.g. Wilson, op. cit., 13.
35 Harrison stresses the 'softer' attitude (op. cit., 226–7).
36 One of Wilson's chief exhibits for the later, weaker view is the following bit of internal dialogue: Descartes suggested that one might argue that 'since the organs of their [beasts'] bodies are not very different from ours, it may be conjectured that there is attached to these organs some thought such as we experience in ourselves. . . .' To this, he has 'nothing to reply except that if they thought as we do, they would have an immortal soul like us. This is unlikely. . . .' (AT iv. 576; cf. AT v. 277–8.) But this very paragraph contains statements that by her lights ought to fit better with the allegedly earlier, stronger view: e.g. 'I know that animals do many things better than we do, but this does not surprise me. It can even be used to *prove* that they act naturally and mechanically, like a clock which tells the time better than our judgement does' (ibid., italics added).
37 *Port-Royal Logic*, IV. art. 12.
38 Ibid.
39 This power is said to be 'naturally equal in all men' (ibid.), and the term 'naturally' (or 'by nature') indicates God-givenness (cf. Meditation VI).
40 AT vi. 2. Descartes of course requires us to go against *le bon sens* in the *Meditationes* (to suspend judgement on what 'no sane person has ever seriously doubted', AT vii. 16). He is, however, careful to stress that 'no danger or error will result from my plan, and I cannot possibly go too far in my distrustful attitude . . . because the task now in hand does not involve action but merely the acquisition of knowledge' (AT vii. 22). So he is not enjoining us to act contrary to our God-given practical reason in the conduct of life, but in a quite different enterprise.
41 Anita Avramides' otherwise excellent article 'Descartes and Other Minds', *Teorema* vol. 16 (1996), 27–46, is flawed by her reading 'morally certain' as meaning 'highly likely'.
42 Gordon Baker has suggested an alternative reading. Instead of tying moral certainty so tightly to responsible use of good sense, one might tie it more tightly to truth: if what you thought was morally certain turns out to be false, then it was not after all morally certain. This would imply that there are *two* possible gaps between 'thinking you are morally certain' and 'being morally certain': one would involve negligence (thinking you had made the best use of good sense when in fact you had not), the other evidence that was unavailable to you even when you had made the best use of good sense. My reading only allows the first kind of gap. On either reading, however, tying moral certainty more tightly to one of the two concepts (responsible use of good sense, truth) necessitates loosening its bonds with the other.
43 Here there seems to be a contrast between 'good sense' on the one hand and the pure faculty of judgement on the other, at least on the interpretation I am offering here. In both cases, it is obviously possible that someone can take something to be certain when it is not. For example, one can take oneself to

have fulfilled one's investigative duties when in fact one has neglected some of them, and in like manner one can take oneself to perceive clearly and distinctly when in fact one does not. But in the case of the pure faculty of judgement, if one really does clearly and distinctly perceive, then what one so perceives is guaranteed by God to be true; whereas in the case of good sense, even if one has made the most responsible use of this faculty, what one thus perceives *may* still be false: its truth is not directly underwritten by God.

44 Following the French, I have added a comma after 'life' to disambiguate this clause.

45 The point might appear to be that machines require different organs for each action, there are an infinite number of contingencies of life in which our reason makes us act, and it is impossible for there to be a (finite) machine with an infinite number of organs. But I find it hard to see why the impossibility here would only be *moral* impossibility. In any case what is it supposed to mean to say that there are an infinite number of contingencies of life? The parallel in the text relating to the other test is 'whatever is said in its presence'; are 'an infinite number of things said in its presence'?

46 Is he saying that we can *only* be morally, not absolutely, certain that our fellow human beings are not machines? Surely not: just as we can 'see' that infants are of the same nature as adults, we can 'see' that other human beings are of the same nature as ourselves, hence have rational souls. Note however that *particular* judgements (e.g. 'That creature over there has a rational soul') will not be absolutely certain; the assignment of particular individuals to species is always liable to error.

47 Of course one might argue that it is morally impossible for such a pretence to be sustained for any significant period of time. Cf. Wittgenstein, *Philosophical Investigations* §391: 'I can perhaps imagine (though it is not easy) that each of the people whom I see in the street is in frightful pain, but is artfully concealing it. And it is important that I have to imagine an artful concealment here.'

48 'Now in just these two ways we can also know the difference between man and beast': AT vi. 57.

49 AT vi. 58; cf.: 'If you teach a magpie to say good-day to its mistress . . . this can only be by making the utterance an expression of one of its passions . . . [e.g.] the hope of eating' (AT iv. 574).

50 Thus Descartes would not deny that animal sounds may be 'meaningful' in the sense that Montaigne uses it here: 'The horse knows there to be anger in a given bark of a dog; but that same horse does not take fright when the same dog makes some other meaningful cry'. He would object to the word 'knows', but point out that it is clear from the context that 'knows there to be anger' just means 'takes fright'.

51 AT vi. 58.

52 AT iv. 575.

53 Cf. Montaigne: 'We have some modest understanding of what they [the beasts] mean: they have the same of us, in about equal measure.'

54 AT vi. 57–8.

55 'Incredible' thus stands to moral impossibility (or 'incredibility of the denial' stands to moral necessity) as 'indubitable' stands to absolute necessity. Again, for reasons stated earlier, 'incredible' is not to be confused with 'improbable'.

56 AT vi. 58.

57 He of course allows that animals have corporeal souls.

58 AT iv. 576.

59 Insofar as essences or natures go along with species, this clearly demonstrates a transformation in the (still unstable) concept of a species, as we say that there are many species of animals. But it is not as though Descartes would deny this.

Discernable in the background of Descartes' reasoning here is the tree of Porphyry. From this point of view, what counts as a genus, what as a species, depends on where you are on the tree. Towards the top, 'animal' is a genus of which there are *two* species, 'rational' and 'non-rational'; but at the next level, 'non-rational' is a genus of which there are (again) two species, and so on. Hence at one level (the one that matters for present purposes) oysters and monkeys, belonging to the same species, have the same nature; at a lower level they belong to different species, hence have different natures, though they will still essentially share the absence of a rational soul.

60 AT xi. 279; italics added.

61 Modern readers are bound to want to ask: but what would Descartes say if a non-human animal were to be discovered that *did* speak? There are researchers – e.g., Sue Savage-Rumbaugh, Stuart G. Shanker, and Talbot J. Taylor, *Apes, Language and the Human Mind* (Oxford, 1998) – who want to argue that bonobos have already been shown to do so. But, first, their investigation of language has a different focus than Descartes': they aim to show that bonobos produce and understand utterances with a certain degree of syntactic complexity and linguistic creativity, *not* to show that bonobos' speech is an expression of thought (in Descartes' sense, which ties in with freedom and moral responsibility) which indicates that they have rational souls (which are immortal and will be judged on the Great Day). The former is something that perhaps could be *discovered* empirically (even if sceptical linguists keep moving the goalposts!); the latter not. Second, nothing that Descartes says *rules out* the possibility that it could come to be morally certain that bonobos spoke, hence thought and had rational souls. This would make it morally certain that they had a different nature from other non-human animals.

18 Descartes' cardiology and its reception in English physiology

Peter Anstey

Introduction

The story of the reception of Cartesian physiology in England promises to be both rich and fascinating, but perhaps owing to its complexity and scope it is not particularly well researched and much of the story has yet to be told. Part of the problem is knowing where to start. One could focus on any of the following aspects of Descartes' physiological thought: the theory of muscle movement, his neurophysiology, the physiology of perception, respiration, the theory of innate heat, embryology or cardiology. Yet given the systematic nature of Descartes' thought and the interrelated nature of physiological research in England, it is difficult to isolate any one of these for special treatment without impinging on the others. Then there are the wider issues of greater philosophical import, such as the relation between Descartes' physiology and his psychology, or its relation to his concepts of life, health and death. Equally, one could start with the philosophical, theological, social and even technological conditions that prevailed in England and the extent to which they influenced the circulation and evaluation of Cartesian physiological ideas in the last six decades of the seventeenth century. In short, the number of topics is legion, large tracts of the terrain remain uncharted and a systematic study seems some way off.[1]

What is offered here is a study of the fate of one particular physiological theory of Descartes and those parts of the philosophical superstructure that held that theory in place. It is a study of the reception in England of Descartes' doctrine of the movement of the heart. As such it is a very modest contribution to what remains a desideratum in Cartesian studies, a systematic account of the reception of Cartesian physiology in England. The study will proceed as follows. First, I shall outline the central tenets of Descartes' account of the motion and function of the heart and the anatomical arguments he adduced in support of it. Second, I shall attempt to explain the importance that Descartes placed on his cardiology. Then I shall survey the reception that his views received in England. I begin with an analysis of Harvey's treatment of Descartes' views, then I turn to

Kenelm Digby, Henry Power and Robert Boyle. The survey culminates in a discussion of the work of Richard Lower who provided the decisive refutation of the Cartesian view in 1669. The treatment is chronological and is necessarily selective. In discussion of each physiologist, I shall examine their response to both the Cartesian account of the movement of the heart and the mechanistic physiology that, in Descartes' view, gave his theory its importance. Next I explore some of the historiographical implications of the survey. It is argued that the traditional view of Lamprecht needs an important qualification.[2] Lamprecht claimed that the initial stage in the reception of Cartesianism in England was one of enthusiastic endorsement, but what we will encounter as the survey unfolds is that virtually all of the physiologists and natural philosophers in England rejected the Cartesian view. As for the vexing question as to why the English uniformly rejected Descartes' view, this remains a residual puzzle. My conclusions are only negative. I claim that this rejection was not motivated by a particular metaphysical or natural-philosophical orientation, for those who engaged with Descartes' ideas on cardiology represent a broad spectrum of views from vitalism to strict mechanism. It seems that the causes of this rejection lie elsewhere, and it is a subsidiary aim of this study to highlight the need for further investigation of this issue.

Descartes' account of the movement of the heart and blood[3]

(i) Movement of the heart

According to Descartes, there are two phases to cardiac motion. First there is the diastole, the active phase when the cavities of the heart dilate. Diastole is also the cause of the visible manifestation of the heart's movement. As the heart dilates in diastole it shortens, and as it swells it strikes the wall of the chest. The second phase is systole, the phase in which the heart lengthens and the ventricles of the heart contract. These two phases of cardiac motion are entirely in keeping with the Galenic view.[4]

(ii) Movement of the blood

Descartes' main departure from the Galenic tradition was his acceptance, following Harvey, of the circulation of the blood. On the Galenic view, the venous and arterial systems are thought to be almost completely discrete.[5] The movement of the blood was bi-directional; the heart and arteries would draw and drive it as they swelled and contracted. However according to Descartes, the blood circulates around the body in one direction. It enters the right ventricle[6] drop by drop through the atrioventricular valve. There it expands causing the dilatation of the ventricle and the outflow of the rarefied blood into the pulmonary artery.[7] After passing through the lungs where it is cooled, thickened and mixed with air,[8] the blood returns to the left ventricle, thus completing its pulmonary transit. It enters drop by drop into the left ventricle and, on being rarefied there, is forced into the aorta and thence throughout the arterial system. It moves from the arteries to the veins through the (as yet unobserved) capillaries[9] and then through the veins back into the right ventricle of the heart. A second point of departure from the Galenic view is Descartes' claim that the blood leaves the ventricles on diastole because of the blood's expansion, rather than on systole because of the heart's contraction.[10]

(iii) Cause of the movement of the heart and blood: Descartes' ebullition theory

What is it then that accounts for the movement of the heart and blood? What is the efficient cause of their movement? According to Descartes, there is a fire in the heart, *un de ces feux sans lumière*, which burns continually.[11] In fact, there is more heat in the heart than in any other part of the body.[12] On account of its heat this fire 'rarefies the blood in the heart, separates the tiny parts of the blood, one from the other, and divides them up and changes their shapes in all the ways we can imagine'.[13] This rarefaction is instantaneous.[14] All or most of the particles of the liquid, which are randomly dispersed throughout its volume, undergo some simultaneous change, which causes them to take up significantly greater space. As the blood is rarefied, the heart swells and first forces the atrio-ventricular valves to close, thus preventing more blood from entering the ventricles. Then the pressure in the ventricles forces the semi-lunar valves to open and almost all of the rarefied blood exits through them causing the arteries to swell. All this happens in an instant. Then, as the blood cools, the arteries and ventricles contract, the semi-lunar valves close and the whole process is repeated. Furthermore, Descartes told his correspondent Plempius that the small portion of blood that remains in the ventricles takes on a yeast-like property which facilitates the rarefaction process as this residual blood readily mixes with the incoming blood.[15] The cause then of the heart's movement is an ebullition or enkindling of the blood in the ventricles.

There was some development in Descartes' theory of ebullition over time. For example, the fermentative ebullition mentioned in the letter to Plempius is not to referred to in the earlier *Discours de la Méthode*. Moreover, Roger French has pointed out that Descartes further modified his early account of the rarefaction process in a letter to Regius of 24 May 1640, where he speaks of chyle mixing with blood in the heart and 'being changed into true and perfect blood by a pulsific ebullition'.[16] However, neither this 'concoction' theory nor the fermentation view is mentioned in the *Passions* or the *Description du corps humain*, both of which were commenced in the latter half of the 1640s, years after the Plempius and Regius correspondence. We can only speculate as to why Descartes reverted to the simplified theory in these later works, but his final comments in his second reply to Plempius suggest that he considered a more sophisticated account of ebullition as non-essential.[17]

Now it is important to note that there is no conception here of the heart being a muscle. Rather the heart functions something like a furnace. The organ itself is entirely passive, its movement being caused by the constant expansion and contraction of the blood that enters it. To be sure, there is a constant agitation of subtle particles that constitute its innate fire, and Descartes' talk of contraction seems to presuppose some elastic qualities in the fibres of the heart, but the organ itself is a passive receptacle. 'The entire fabric of the heart, the heat in it, and the very nature of the blood, all contribute' to the rarefaction of the blood which in turn causes the movement of the heart and blood.[18] Thus, the heart is the source of the heat of the blood and consequently of the heat of the whole body.

(iv) Anatomical observations in support of Descartes' theory

What then were the anatomical observations that Descartes adduced in support of his particular explanation of the movement of the heart? Descartes lists them in the *Description du corps humain*. First, when the heart becomes hard it increases in size. This increase is not great because of the transverse cords that inhibit its free expansion, but it is enough to have led the majority of medical men to conclude that it dilates during this phase.[19] Second, he claims that if you remove the pointed end of the heart of a young rabbit, you can see that when the heart hardens the cavities become slightly wider.[20] Third, when the blood leaves the heart it is qualitatively different from when it enters it, 'it is much hotter, more rarefied and more agitated'.[21] We can either explain this by appeal to some (occult) faculty in the heart, or by appeal to Descartes' ebullition theory. Surely, argues Descartes, given the nature of the heat of the heart and the unintelligibility of a pulsific faculty as postulated by Harvey, the Cartesian explanation is the truth of the matter.

The importance of the motion of the heart

Descartes claims that his account of the movement of the heart is absolutely central to his anthropology. In the *Description du corps humain* he tells us that

> it is so important to know the true cause of the heart's movement that without such knowledge it is impossible to know anything which relates to the theory of medicine. For all the other functions of the animal are dependent on this.[22]

And to Mersenne he went so far as to claim:

> I am prepared to admit that if what I have written on this topic [the movement of the heart] or on refraction . . . turns out to be false, then the rest of my philosophy is entirely worthless.[23]

What is it about Descartes' account of the movement of the heart and blood that he believes is so critical to his account of humans, and ultimately to his whole natural philosophy?

Part of the answer has to do with Descartes' firm belief in the efficacy of a new application of mechanical or what the English called 'corpuscular explanations' to physiological problems. They were to replace the old scholastic explanatory categories. At the end of the *L'Homme* Descartes tells us that:

> I should like you to consider . . . all the functions I have ascribed to this machine – such as . . . the beating of the heart and arteries . . . follow from the mere arrangement of the machine's organs every bit as naturally as the movements of a clock or other automaton follow from the mere arrangement of its counter-weights and wheels.[24]

This appeal to *l'homme* as a machine is accompanied by what was to become a standard anti-Aristotelian move, one that is almost axiomatic for the mechanical philosophers. It is the denial of the need to appeal to occult qualities or faculties. It is a point that Descartes thought was particularly telling against Harvey's theory of the movement of the heart. Again in the *Description du corps humain* he says,

> [i]f, instead [of Harvey's view], we restrict our consideration to the expansion of the blood which must follow necessarily from the heat . . . it will be plain to see that this expansion alone is sufficient to move the heart in the way I have described, and also to change the nature of the blood. . . . Thus we do not have to suppose, in order to explain all this, any unknown or strange faculties.[25]

But there is more to the importance of his cardiology than merely the adoption of new explanatory categories, for there is an important reductive claim here. Continuing our previous quote from the conclusion of *L'Homme*, we find Descartes saying,

> [i]n order to explain these functions, then, it is not necessary to conceive of this machine as having any vegetative or sensitive soul or other principle of movement and life.[26]

Descartes' mechanistic account of the body, revolving as it does around the notion of innate heat, replaces the scholastic vegetative and sensitive souls.[27] His account of the physiology of *l'homme* marks a decisive break from the neo-Platonic conception of *spiritus* that dominated late scholastic psychology. From now on *l'homme* was to be considered as a substantial unity of *res extensa* and *res cogitans* with no spirits of intermediate ontological status, with no plastic principle. In this, Descartes was consciously relocating the boundaries of psychology, that is, the study of the soul and its faculties.

Now it must be admitted that all this is widely appreciated.[28] Yet, it still does not completely account for Descartes' insistence on the truth of his theory of the movement of the heart and blood. For it is clear that one can agree with him that the new corpuscular explanations are more adequate than the Aristotelian ones, without agreeing with Descartes on the details of his explanation of the motion of the heart. And Descartes surely could have seen this. He was acutely aware of his divergence from the great Harvey in this regard. What seems to be driving Descartes here is his genuine belief in the superiority of his own determinate mechanical explanation of the physiology of the heart and blood. In the *Discours de la Méthode* he says:

> Now those who are ignorant of mathematical demonstrations and unaccustomed to distinguishing true reasons from probable may be tempted to reject this explanation [of the motion of the heart] without examining it. To prevent this, I would advise them that the movement I have just explained follows from the mere arrangement of the parts of the heart. . . . This movement follows just as necessarily as the movement of a clock follows from the force, position, and shape of its counter-weights and wheels.[29]

It is not just that mechanical explanations are vital for the correct explication of the cardiovascular system, but that this particular explanation is definitive.[30] To Plempius he wrote of his account of the ebullition of the heart, that 'nothing that we perceive by the senses seems to me more certain than this'.[31] What we shall see, as we examine the English reception of Descartes' physiology of the heart, is that this was the precise point of disagreement between the English physiologists and Descartes. Many of them took over the new explanatory categories with enthusiasm, but they rejected the actual explanations themselves because they were at variance with anatomical observation.

The response of William Harvey[32]

William Harvey, England's Asclepius,[33] discusses Descartes' theory in his *Second Essay to Jean Riolan*, published in 1649. The first reference to Descartes' view is by allusion only. There Harvey denies that the heart 'is like a sort of burning coal or brazier or hot kettle, the source of heat and blood'. Rather, the blood is the source of the heart's heat.[34] But Harvey quickly proceeds to an explicit discussion of Descartes' views.[35] He is clearly familiar with the Descartes/Plempius correspondence, because he begins his discussion with a reference to Descartes' view on the pulsation of the exposed heart of a fish.[36] This anatomical observation was originally brought as a counter-example to Descartes' view by Plempius, but Harvey uses it simply to point out the issue of disagreement between himself and Descartes. Descartes and his supporters claim that the heart dilates when it becomes hard. 'When it is erected, rises, and becomes strong, they assert that it is enlarging and opening out and that its ventricles are in consequence more capacious.'[37] But this is the opposite of Harvey's view. For him, the heart is contracting when for Descartes it is dilating.[38] Where then, according to Harvey, did Descartes go wrong?

First, Harvey simply disagrees with Descartes' observation. He claims that the heart is contracting when it hardens. Then he points out that there are really three phases to the movement of the heart. There is the relaxed presystolic heart that is devoid of all movement and not distended, then there is contraction or systole and finally diastole when the heart is distended. The crucial point that Descartes seems to have missed, according to Harvey, is that 'the same thing is not the cause of distension, relaxation and constriction. Rather are contrary effects due to contrary causes'.[39] He then appeals to the parallel of antagonistic muscles of adduction and extension, and claims that 'for contrary and diverse movements contrary and diverse active organs have of necessity been fashioned by nature'.[40] His view is that the ventricle is distended by the inflow of blood resulting from the contraction of the auricle and contracted by its own effort.[41] By contrast, Descartes attributes the same cause to systole as to diastole, namely the effervescence or boiling up of the blood and its cooling. Harvey rejects this because of the speed of the strokes of the heart which is faster than any fermentation of liquids, and because of the observation that the ventricles are distended and filled by the contraction of the auricles.

However, Harvey's was not a full refutation of the Cartesian view. He had contradicted Descartes' observation of the contractive phase of the heart's movement, and he had adduced the evidence of comparative fermentation processes being rather slow, but he had not decisively refuted the ebullition theory, for Harvey himself believed in the ebullition of the blood. In the very work in which he attacks the Cartesian view, Harvey tells us that

> the blood contained in the veins and present in, so to speak, its reservoir where it is most abundant (. . . the right auricle), slowly growing warm from its internal heat and becoming more rarefied, swells up and rises in the way fermenting things do. This dilates the auricle which, contracting with its pulsific faculty, drives the blood more frequently and speedily into the right ventricle of the heart.[42]

Moreover, mention of the 'pulsific faculty' reminds us that Harvey had not answered Descartes' key objection to his own view, that it cannot account for the qualitative change in the blood that appears to occur in the heart. To be sure, Harvey explicitly addresses the question of the difference between venous and arterial blood in his *Second Essay to Jean Riolan*, but he is at pains to minimise their differences and to emphasise their substantial equivalence. Now what is important to note here is the role of anatomical observation. Descartes was a mechanist, Harvey a vitalist. So the two differed markedly in the range of explanatory categories to which they were prepared to appeal. Of course, Harvey was not averse to mobilising mechanical analogies at times.[43] But he was fundamentally opposed to a thorough-going mechanistic analysis of humans, one that would for example, give a corpuscular analysis of the constituents of the blood. As Walter Pagel has so ably demonstrated, Harvey's theory of the blood as the life spirit was developed in part as a reaction against mechanistic and materialistic theories.[44] But, in spite of their divergent philosophical stances, the watershed issues between Descartes and Harvey were observational. The issue was just what anatomical observations would count in favour of which theory. Harvey had simply not brought enough convincing observational evidence to undermine the Cartesian view, particularly in the light of his own acceptance of an ebullition theory, the theory which was so central to Descartes' view. But given Harvey's eminence, his explicit opposition to Descartes' view set the problem up as an issue that had to be resolved. A solution to the problem became a desideratum in English physiology.

Within four years of the publication of the *Second Essay to Jean Riolan* an edition of Harvey's collected writings was published in England.[45] The surprising feature of this work is that it included a *Discourse of the Heart* by a Dutch physician called James de Back. De Back's work had in fact been published in Latin in 1648 in Rotterdam, but it first appeared in English in this 1653 edition of Harvey's writings. What is significant about de Back's discourse is that it contains two lengthy critical discussions of Descartes' account of the movement of the heart, and it is hard to resist the conclusion that one of the reasons for the inclusion of de Back's discourse in the collection of Harvey's writings was the anti-Cartesian polemic that it contains.[46]

Finally, there is a lesson here in how not to read the Harvey/Descartes controversy. As Geoffrey Gorham has recently pointed out, it is important to stress that we do not have here a dispute between an archetypal rationalist and a prototypical empiricist.[47] It is not the case that Harvey's account of the movement of the heart, the correct view as it turned out, was based purely on observation and that Descartes' theory was deduced from his principles with the observational evidence selectively interpreted to fit the theory after the event. The facts are that most of the observational evidence was identical for both views, that both physiologists had theoretical agendas (albeit vastly different), that there were elements in both theories that we now believe to be patently false and that in their lifetime the issue remained unresolved. The disparities in the two accounts of the motion of the heart are instructive of their proponent's respective philosophies of science, but the rationalist/empiricist dichotomy is of limited utility in cashing just what these differences amount to.[48]

The response of Kenelm Digby

Descartes' *Discours de la Méthode* was published in 1637, but Harvey did not publish his reply to Descartes' account of the movement of the heart until 1649. Some five years before the appearance of Harvey's *Second Essay to Jean Riolan* the English polymath Kenelm Digby included an extended critical treatment of the Cartesian theory in his *Two Treatises*. This is not to say, however, that Digby's response to Descartes preceded that of Harvey, for internal evidence enables us to date the composition of the *Second Essay to Jean Riolan* at c. 1641–1646.[49] Thus, it appears to be roughly contemporaneous with Digby's work. However, the discussion in Digby's *Two Treatises* does represent the first explicit critical response to the Cartesian theory of the motion of the heart by an Englishman.[50]

Digby's insatiable appetite for intellectual innovation meant that he had acquired and digested the *Discours* within four months of its publication. He wrote of the book to Hobbes from London on 14 October 1637, saying that 'I doubt not but you will say this is a production of a most vigorous and strong braine; and that if he were as accurate in his metaphysicall part as he is in his experience, he had carryed the palme from all men living'.[51] Yet it was not long before Digby was questioning Descartes' 'experience'. Digby has no less than eight points of disagreement with Descartes' account of the movement of the heart.[52]

His first point is that, 'both Galen and Doctor Harvey do shew, that as soon as the bloud is come into the hart, it contracteth it selfe'. Second, against Descartes' claim that the heart is like a passive bladder, 'Doctor Harvey prooveth that when it is full, it compresseth it selfe by a quicke and strong motion' and that when it is empty 'it returneth to its natural dilatation, figure and situation', so that 'it appeareth to be of such a fibrous substance, as hath a proper motion of its owne'.[53] But neither of these points present specific anatomical observations to counter Descartes' view, instead they are arguments from authority. Third, he objects to the thesis that the motion of systole and diastole can be proportional on Descartes' theory, because there is no cause of systole other than the 'going out of the vapour'. Ostensibly this is a strong argument against the Cartesian position, but as we shall see below, Digby upheld the view that both systole and diastole were active phases of the heart's movement and that diastole was the stronger motion. This contradicts Harvey's innovation, which was to point out that the truly active phase is systole alone. Fourth, Digby points out that Descartes cannot explain why the blood does not enter the ventricles until all the vapour is evacuated. Why for instance, does not new blood drip in as the pressure of the vapour decreases in the ventricles, thus keeping the heart continually dilated? Fifth, an excised viper's heart will beat for 24 hours or more 'without succession of bloud to cause the pulses of it', and other animal members continue to move after being severed from their bodies. This objection had already been made against Descartes by Plempius and was discussed at length by Descartes in his reply. Sixth, experience shows that, contra Descartes, the heart is softest when full of blood and hardest when empty, and that the flow of blood is strongest towards the end of systole. Seventh, Descartes can really only account for the movement of vapour from the ventricles and not the liquefied blood 'since it lyeth lower then the steame, and further from the issue that letteth it out'. Yet, claims Digby, this contradicts Harvey's observation that from the arteries 'bloud will gush out by spurtes att every shooting of the hart'. Finally, given the seventh point, the arteries would be full of steam, whereas 'the chiefe filler of them is blood'.

Now, Digby's talk of the heart's 'natural dilatation' suggests that he does not have a thoroughly Harvean understanding of the motion of the heart and blood. And indeed the account that he offers in place of Descartes' is decidedly unHarvean, and in some ways, less credible than that which it aims to replace. Furthermore, some of the elements in Digby's explanation of the heart's movement are closer to that of Descartes than Harvey. Digby posits three causes of the motion of the heart and blood. He begins with the general claim that, rather than an ebullition, the cause of the motion of the heart must lie within the heart itself. Then comes the first cause of the heart's moving; it is the 'heate or spirits imprisoned in a tough viscous bloud' that is in every part of the heart. These spirits give the heart its 'vertue of moving', for every part of the heart moves. He adduces five reasons in support of this including, what for Digby was a common refrain, that 'Doctor Harvey assureth us by experience'.[54]

He then identifies three sorts of fibres in the ventricles that are a second cause of its movement. There are longitudinal, horizontal and transverse fibres which 'being of the nature of such things as will swell and grow thicker by being moistened, and consequently shrinke up in length and grow shorter, in proportion to their swelling thicker . . . it must of necessity follow, that when the bloud falleth into the hart . . . the fibers being therewith moystened, they will presently swell in roundness and shrinke in length'. The third cause of the heart's movement is the most bizarre. Having observed that the heart 'is fixed to the body by its base; and hangeth loose att the cone', he goes on to explain diastole and systole by an appeal to gravity. An important step in the explanation is an explicit denial of the Harvean claim that the active phase of the heart's motion is the systolic phase. He says 'although Doctor Harvey seemeth to allow the opening of the hart to be no motion; but rather a relenting from motion; nevertheless (me thinketh) it is manifest, that it is not only a complete motion, but in a manner the greater motion of the two'.[55] The reason is that,

> the weight of the blood which is in the auricles, pressing upon the valvulas or dores that open inwardes, maketh its way litle and litle into the ventricles of the hart where it must necessarily swell the fibres; and they being swelled must needes draw the hart into a roundish and capacious figure; which the more it is done, the more bloud cometh in; and with greater violence.[56]

So the swelling of the fibres causes the heart to become round and dilate which in turn enables more blood to flow in. What Digby envisages is, in effect, two stages of diastole, the first of which bears some resemblance to the Galenic diastole insofar as the blood enters the ventricles in virtue of their dilation,[57] and the second resembling that of Harvey in so far as the ventricles lengthen as they fill with blood. But it is his explanation of the cause of systole that is truly remarkable. According to Digby, during the second stage of systole the heart descends according to gravity until with a 'lively jerke' it springs upwards to the breast and the blood spurts out of the outwardly opening valves. He seems to conceive of the heart as an elastic pouch constantly bouncing up and down in the breast.

After addressing some obvious objections, such as why the heart continues to beat when a person is hanged upside-down, Digby sums up his theory thus: 'In conclusion, we see, the motion of the heart, dependeth originally of its fibers irrigated by the bloud: and not from the force of the vapour as Monsieur des Cartes supposeth.'[58] Yet he immediately proceeds to speak of the blood being warmed and spiritualised and 'boyled in this furnace', and speaks of the blood receiving a 'new rarifying' in the heart. His likening of the heart to a furnace, his account of blood making its way 'litle and litle' into the ventricles and talk of rarefaction are uncomfortably close to the Cartesian view, especially when one considers that this section sets out to refute Descartes' account.

The whole tenor of Digby's account is that of the armchair physiologist. Unlike Descartes who, in the *Discours*, urges his reader to procure a heart before reading on or Harvey's *De Motu Cordis*, the only first-hand observation that Digby appeals to is the movement of the severed parts of a viper's heart which he happens to have observed 'upon occasion of making the greate antidote, in which vipers harts is a principall ingredient'.[59] What then is the significance of Digby's response to Descartes? As a natural philosopher Digby is difficult to classify. He really occupies his own niche in the period; a Catholic Aristotelian mechanist who was admired but not followed. His account of the movement of the heart appears to have convinced no one and to my knowledge was never even seriously discussed. Its significance lies in its chronological priority and its allegiance to Harvey.

The response of Henry Power

Henry Power was perhaps the first English natural philosopher who was both strongly influenced by Descartes and addressed the problem of the motion of the heart.[60] Born in 1623 he entered Christ's College Cambridge in 1641 and commenced medical studies in 1646. In that year he received advice from his mentor Sir Thomas Browne to 'make yourself master of Dr Harvey's piece De Circul. Sang'.[61] Power took the advice, but read further afield, telling Browne in 1648 that he had 'run through the whole body of Anatomy Insisting upon Spigelius, Bartholinus . . . but especially Harvey's Circulation, & the two Incomparable Authors, DesCartes, & Regius, wch indeed were the only two that answer'd my doubts & Queries in that Art'.[62] He could only have read Descartes' *Discours* at this time, but Descartes' physiological views were also spelt out in Regius' *Fundamenta physices* (1646) and *Fundamenta medicina* (1647) which were very popular in England and which we know Power read.[63] The early influence of Regius' physiology is further evident in a letter to Browne in August 1649 in which Power relates the Cartesian's views on the motion of the heart and lungs in hibernating animals.[64] Finally, we must not forget that the most eminent early Cartesian in England, Henry More, was a fellow at Christ's College and most likely influenced the young scholar Power.[65]

It is rather surprising then, when we turn to Power's manuscript on the circulation of the blood, written in 1652, that his cardiology is thoroughly Harvean. There are the standard appeals to machines, like the comparison of observation of the palpitations of a shrimp's heart which 'as through an amber or crystall cased watch the Automaticall Motion of the Nutts and Wheeles are discoverable'.[66] But we have seen that these are to be found even in Harvey. Power's detailed description of the motion of the heart and the circulation of the blood concur with Harvey's on every major point. With Harvey he claims that the blood is ejected on systole,[67] that the heat of the blood is greater than that of the heart, that the movement of the heart arises from its own pulsific virtue[68] and that '[w]hen the Heart is in it's Systole or Contraction, then doe all the Arteryes of the Body pulse, and are in their Dilatation'.[69] Each of these points is at odds with the Cartesian account, yet throughout we find Power referring to Regius and even mentioning Descartes' belief in capillaries.

When we turn to Power's only recognised[70] published work, his *Experimental Philosophy* (1663), we find him to be a Cartesian natural philosopher. He establishes in his preface the Cartesian principles upon which the work is based and throughout we find him defending various Cartesian theses such as Descartes' account of fluidity, his theory of colour and the denial of a vacuum.[71] But this work does not deal with the problem of the motion of the heart and apart from mentioning, in passing, the Harvean thesis that the blood is perfected in the heart,[72] there is little in it that can advance our understanding of his reception of Cartesian cardiology. However, Power's *Analogia Physico-chymica* (1666), also unpublished, does contain some interesting developments in Harvean physiology. As Charles Webster has pointed out, Power in this work regards 'the ventricular blood of the heart as the seat of elaborate exothermic chemical processes, which synthesized blood from chyle, heated the heart and gave rise to the ebullition of "aetheriall" vital spirits'.[73] Harvey's auricular ebullition had become something analogous to the ventricular concoction about which Descartes wrote to Regius. Yet Power continued to maintain, contra Descartes, that the cause of the expulsion of blood from the heart is the constriction of the ventricle on systole; '[t]he right Auricle of the heart receiving a continual supply of blood and chyle from the Vena Cava at every Systole or constriction throws it into the right Ventricle, thence it is ejected by the hearts systole through the Pulmonary Artery.'[74]

But if Power was moving towards Descartes on the question of ebullition, he was diverging from him on the question of the ontological status of spirits, a subject to which he devotes a whole chapter in his *Experimental Philosophy*. For Power, spirits on the one hand were given a corpuscular interpretation as being the finest particles of the subtle matter,[75] while on the other they appear to have an intermediate ontological status somewhere between corporeal matter and immaterial substance. In their most noble form as animal spirits, they are the 'immediate Instrument of the Soul, both of Sense and Motion',[76] thus somehow bridging the corporeal and incorporeal. Moreover, spirits pervade more than just the biological realm. They also function in an analogous way to seminal principles in the formation of minerals. Charles Webster concludes that for Power the 'spirits enabled him to evade the philosophical problem of the Cartesian dualism, to achieve a synthesis between the mechanical and neo-Platonic philosophies'.[77]

Power's doctrine of *spiritus* would certainly have been influenced by the likes of Glisson, More and Willis. And it is worth mentioning at this juncture that Power's Cambridge mentors had, by the late 1650s, also expressed their disagreement with Descartes' account of the movement of the heart. Glisson's arguments against Descartes have survived in some manuscript notes entitled 'The opinion of Descartes on the motion of the heart is not in keeping with the truth'.[78] And by 1659 More had expressed his disagreement with the mechanistic physiology of Regius and Descartes. In the *Immortality of the Soul* he speaks of Regius' conceit

> That whatever is in the rest of the Body, may come to pass by powers merely Mechanical; wherein he does very superstitiously tread in the footsteps of his Master Des-Cartes. But for my own part, I cannot but dissent.

He goes on to speak of the 'deepest or lowest' faculty of the soul as the

> Plastick power we have already spoke of, in virtue whereof is continued that perpetual Systole and Diastole of the Heart, as I am more prone to think then that it is merely Mechanical.[79]

If this is an indirect criticism of Descartes' theory of the motion of the heart, Ralph Cudworth, the other leading Cambridge neo-Platonist, was soon to be more explicit. In his *True Intellectual System of the Universe*, completed by 1671, he tells us,

> the Cartesian attempts to solve the motion of the heart mechanically, seem to be abundantly confuted by autopsy and experiment, evincing the systole of the heart to be a muscular contraction, caused by some vital principle, to make which, nothing but a pulsific corporeal quality in the substance of the heart itself, is very unphilosophical and absurd.[80]

It should not be surprising then to find that Power, the eclectic Cartesian, accepted a natural philosophy based on Cartesian principles, but welded onto it Harvean physiology and neo-Platonic conceptions. What is important for our study of the reception of Cartesian physiology is that Power regarded neither his neo-Platonic account of *spiritus*, nor his Harvean account of the movement of the heart, as undermining the integrity of the Cartesian system. This is all the more telling when we consider that Power was the most thorough-going Cartesian physiologist in England. In Power Cartesianism had found an ardent supporter, but not one who was prepared to take on board Descartes' account of the movement of the heart. Clearly this was seen as a non-essential and even dispensable feature of Cartesianism.

The response of Robert Boyle

Another English physiologist who was influenced by Cartesian ideas was Robert Boyle. In contrast to Henry Power, Boyle, by the late 1660s, had adopted Cartesian dualism wholesale. To be sure, he had earlier flirted with various Helmontian notions, and throughout his career as a natural philosopher he maintained a belief in seminal principles. But the latter he interpreted in strictly corpuscular terms.[81] This, combined with his appropriation of Descartes' account of the animal spirits, set him at variance with the neo-Platonic tendencies of the likes of Henry More, Ralph Cudworth and (possibly) Power.[82] Like Descartes, Boyle considered the human body to be a mere machine, albeit an incredibly complicated and admirable one that by its very nature argued for a grand designer. And like Descartes, Boyle was acutely interested in physiology and kept abreast of all the developments in that field. So Boyle, while not an avowed Cartesian, had the metaphysical sympathies and active physiological interest that were required for a serious consideration of Descartes' cardiology.

Thus it comes as no surprise to find that in the first essay of the second part of his *Some Considerations touching the Usefulness of Experimentall Naturall Philosophy*, written between 1656 and 1657, Boyle discusses a range of dissections that he had performed with a view to 'the deciding or reconciling the controversy about the cause and manner of the heart's motion, betwixt those learned modern anatomists, that contend, some of them, for Dr. Harvey's opinion; and others, for that of the Cartesians'.[83] Clearly the issue of the precise nature of the movement of the heart had yet to be resolved. Boyle excised the heart of a flounder in order to settle the issue. He found that the heart, having been cut transversely and dried of blood, 'the severed and bloodless parts held on their former contraction and relaxation'.[84] The clear implication is that since there was no blood present in the ventricles to initiate ebullition, and yet the movement still continued, the Cartesian theory must be wrong. Boyle evidently thought that the issue could be settled by anatomical observation alone, and on the anatomical evidence he sides with Harvey. Yet, Boyle's contrasting of contraction and 'relaxation' shows that he is already predisposed to the Harvean view, for on Descartes' view the contractive phase just is the relaxation of the ventricles.

Boyle might have believed the issue settled, yet as we have seen, Descartes' had already formulated an answer to this very experiment. In his first reply to Plempius he discusses it in detail, and also introduces his theory of a residual yeast-like substance that remains in the ventricles and causes a fermentation which in turn leads to dilatation of the ventricles.[85] According to Descartes, this fermentation can continue for some time. Yet, since Boyle is content with the vivisectional evidence, he does not address this issue. The second point of Descartes that as yet remained unanswered was how to account for the qualitative changes in venous and arterial blood. The inability of the English physiologists to answer this question meant that ebullition theories of the movement of the blood could still earn their keep, and the Cartesian view could not be put to rest. It was only in the work of Richard Lower that the *coup de grâce* was delivered to the Cartesian view.

Finally it should be noted that, while Boyle enthusiastically endorsed some aspects of Cartesianism, he remained open-minded and even sceptical of many of the Frenchman's views. Boyle's nescience on the infinite divisibility of matter, the plenum, the indefiniteness of the universe and the conservation of motion are some of the more obvious examples. But Boyle also questioned some other aspects of Descartes' physiology, not least the role of the pineal gland. This attitude of caution and reservation on Boyle's part no doubt influenced many of the natural philosophers and physiologists within his ambit, and could well have been a strong contributing factor to the absence of any thorough-going adherents to Cartesian physiology in England, with the exception of Antoine Le Grand.[86] This is in contrast to the situation in France where Descartes' view was still being defended by a small group of Cartesians, including the physician Louis de La Forge and Jacques Rohault.[87]

The response of Richard Lower

Richard Lower was a first rate physiologist. He was a protégé of Thomas Willis and closely affiliated with Boyle, Hooke and other leading English physiologists, including John Mayow. The latter, in his *De respiratione* of 1669, accepted a fermentation of the blood in the heart but denied that it is

> probable that the fermentation of the blood conduces, as some think, to the motion of the heart. . . . It is certainly established by actual autopsy that the ventricles of the heart are contracted in its pulse, and not thus dilated by an explosive material.[88]

But Mayow did not address the decisive question of the colouration of the blood. This was left to Richard Lower. In the same year Lower published his *Tractatus de Corde* which he tells us in the dedication is a continuation of the work of Harvey. Harvey had left a number of questions unanswered, and Lower undertakes to answer them. In particular, one of Lower's aims is to give 'a clear picture of the difference in colour of venous and arterial blood'.[89]

His first chapter details the muscular structure of the heart and how the contraction and dilatation of the ventricles follows from this structure. Lower then begins his second chapter with a treatment of the Cartesian theory of the movement of the heart. The fact that the heart is a muscle, which contracts and expands like any other muscle, must raise serious doubts about any account of the movement of the heart that does not appeal to its muscular action to explain its movement. This leads Lower to consider the view of Descartes and his disciple Hooghelande. He says,

> one may perhaps be surprised at the fact that the distinguished Descartes, Hooghelande, and other famous men (because they did not pay close enough attention to the strength of the Heart's structure and its great efforts at every Systole, or to the rapidity of the blood's movement) have been in doubt if the heart causes its own movement, or if it is not rather put into motion by the blood.[90]

After outlining the Cartesian view with some of its developments, he goes on systematically to dismantle it, saying: 'But it will be easy to show that no such ebullition is provoked within the blood, and that no such ferment is present in the Heart.'[91] First he lists more than a dozen observations that count against the Cartesian ebullition theory. The blood is not a liquid given to effervescence since it is too inert, the fermentation theory is false because the structure of the ventricles is such that all their blood is expelled on systole, 'if the blood moves through its own power, why does the Heart need to be so fibrous and so well supplied with Nerves', blood does not enter the ventricles drop by drop, but flows in so as to completely fill the ventricles, when blood is replaced with a less 'volatile' fluid there is no significant change in its movement, and so on.[92] Then he proceeds to discuss the heat of the heart. The denial of ebullition and certain vivisectional observations bring into doubt the Cartesian theory of not only an innate heat in the heart, but also the view that the heart is a source of heat for the blood. Lower concludes,

> I think it is clear that the movement of the Heart does not in any way depend on ebullition of the blood, nor the heat of the blood on any fire within the Heart.[93]

In the third chapter Lower turns to the colour of the blood. He sets out to establish, first, that the difference between venous and arterial blood is independent of heating and, second, that the blood is 'indebted for its deep red colouration' to the absorption of air in the lungs. He proved the former by an open thorax experiment performed on a live dog. Having exposed the trachea and corked it, he observed that the blood in the cervical artery was venous and similar experiments showed that blood found in left ventricle and aorta was dark coloured as well. Then, he set about to establish the contribution of the lungs. The dog having been strangled, he drove the blood from the right ventricle into the lungs which were insufflated (had air blown into them), and found that the blood returning through the pulmonary vein was red 'as if it were being withdrawn from an artery in a living animal'. Lower's conclusion was that the red colouration of arterial blood 'must be attributed entirely to the lungs'.[94] In the lungs the blood absorbs a 'nitrous spirit' which is essential for life. Thus, Descartes' final objection to Harvey had been dispensed with.

Historiographical reflections

This brings us, finally, to some historiographical reflections on the fate of Descartes' cardiology in England. Why did his view fare so badly there? Just how representative is it of the reception of Cartesianism in general in England? And what does it tell us of the status of the mechanical approach to physiology in England in the latter half of the seventeenth-century? These and a host of other questions must be answered if we are to get a balanced picture of the influence of Descartes across the English Channel.

A first way of approaching these issues is to examine just where the different actors in the drama were placed relative to the various intellectual cross-currents that prevailed in the period. One obvious cross-current was the tension between Aristotelian natural philosophy and the new philosophy as represented by Descartes. Here we must place Harvey firmly in the Aristotelian camp, along with his antagonist Primrose. Harvey was a vitalist with many more points of continuity with Aristotelian science than with the mechanical philosophy. Primrose's pamphlet war with Regius places him squarely as a defender of the older natural philosophy. By contrast Power, Boyle and to a lesser extent Digby were champions of the new philosophy, yet they along with Harvey and Primrose were opposed to the Cartesian cardiology. A second cross-current (which cannot really be treated independently from the first) is that between the Galenic *methodus medendi* and the advances in anatomy represented by the work of Harvey and Descartes. The physician Francis Glisson felt this tension acutely and argued that in fact the two could be harmonised,[95] whereas Boyle was critical of the Galenic method.[96] Both, however, were ardent supporters of Harvey and rejected Descartes' cardiology. A third cross-current can be characterised as neo-Platonism versus mechanism. Here we find More, Cudworth and Glisson opposing the stricter form of mechanism propounded by the likes of Boyle, yet again we find both camps rejecting Descartes' view of the heart. The upshot of this rough overview of the diverse allegiances and philosophical predispositions of the various actors is that the rejection of Descartes' cardiology appears to have transcended 'party lines'. It was not just the vitalists, the Galenists, the neo-Platonists or mechanists who rejected Descartes' view. All did.

A second way of setting up the issue in order to draw some historiographical conclusions is to explore any correlations that might exist between attitudes towards the efficacy of mechanical explanations in physiology and the rejection of Descartes' cardiology. Consider a continuum of views on mechanism, ranging from the purest form of mechanism that admits only the primary qualities of inert matter and no capacities or powers, to the most diluted form of mechanism that allows mechanical explanations some very minimal role in scientific explanation. If we align the English philosophers and physiologists discussed above along this continuum we find that they span the whole range. Toward the pure end we find a corpuscularian like Boyle and the physiologists Lower and Mayow. Moving along we find Henry Power who embraced a form of mixed mechanism. He was a mechanical philosopher with great admiration for Boyle and Descartes, but was also influenced by More and Glisson. Toward the impure end of the continuum we find Harvey, who appeals to mechanical explanations in his explication of the heart's motion, but is a vitalist. Further along, beyond Harvey, are Cudworth and More, outspoken opponents of the mechanical philosophy. It is clear then, that the rejection of Descartes' cardiology in England was not tied to a particular predisposition towards a mechanistic approach to physiology. Yet at the same time, it would be too simplistic to claim that the respective attitudes of the English to mechanistic physiology were independent of their views on Descartes' physiology. Henry More, for example, seems to reject Descartes' view just because it is entirely mechanical, whereas Lower's acceptance of mechanical physiology enabled him to prove decisively that Descartes' view was wrong.

Third, we must inquire whether there are any discernible chronological developments in the reception of Descartes' cardiology. This has been the favoured approach in appraisals of the influence of Cartesianism in England and of English physiology generally. For example, Lamprecht has argued that there are three discernible stages in the reception of Cartesian thought in England: first, a period of enthusiastic acceptance in the 1640s and 1650s; second, a period of critical appraisal in the 1660s and 1670s; and third, an authoritative judgment by Locke with the publication of the *Essay* in 1690.[97] Furthermore, it is widely held that mechanical physiology dominated in England from the 1660s until the 1730s.[98] Now, when we turn to the chronology of the reception of Descartes' cardiology, we find that in the 1640s until the mid-1650s the main respondents held either an impure form of mechanism or were not mechanists at all. They comprise Harvey, Digby and those at Cambridge; Glisson, Power and later More. Whereas from roughly the mid-1650s on, those natural philosophers and physiologists who opposed Descartes' view incline to a stricter version of mechanism. They include Boyle, Lower and Mayow. It is therefore possible to construe the context into which Cartesian cardiology was received in England as roughly comprising two stages. The first stage, from the 1640s to the mid-1650s, was characterised by a mixed mechanical approach to physiology. The second stage, from the late 1650s on, was characterised by a pure mechanical approach to physiology. As we have seen, physiologists in both of these stages rejected the Cartesian account of the movement of the heart. Therefore the thesis of Lamprecht, that there was an initial enthusiastic embracing of Cartesianism in England from the 1640s up until the 1660s, must be qualified. While Descartes' natural philosophy was warmly received, the centrepiece of his mechanical physiology was rejected from the outset.

Conclusion

The most striking feature of the foregoing discussion is the almost uniform rejection of Descartes' account of the movement of the heart in England from the early 1640s on. Except for the 'diehard' Cartesian Antoine Le Grand, Descartes' view was dismissed by virtually every major physiologist, natural philosopher and virtuoso who discussed it, and a few minor ones at that. Amongst physicians Harvey, Glisson, and Power rejected it. The Cambridge Platonists Cudworth and More rejected it. The natural philosophers Digby and Boyle had no truck with it, nor did the skilled anatomists Lower and Mayow. Thus, irrespective of their philosophical predisposition and their anatomical expertise, the English would not countenance the centrepiece of Descartes' mechanical physiology. Of course, Descartes' view was not summarily dismissed, at least not by those with a genuine interest in physiology. A case had to be brought against it, and until the work of Lower in the late 1660s there remained the unresolved observational issue of the colouration of the blood. Furthermore, Harvey had complicated the issue by positing some form of auricular ebullition in his later writings. And this, when combined with the influence of ebullition theories promulgated by Dutch physicians such as Hooghelande and Regius, and the lack of a satisfactory account of the colour of the arterial blood, kept ebullition theories alive in England well into the 1660s. But in spite of this, Descartes' view never fared well in England. Perhaps the underlying causes of this were purely social rather than intellectual. Whatever the case, it is certain that we need to explore other dimensions of the reception of Cartesianism before we are in a position to posit causes. I have tried to establish that Descartes' cardiology was uniformly rejected in England. It remains a desideratum to establish why.

Notes

1 For early studies of the reception of Cartesianism in England see M. Nicolson 'The early stage of Cartesianism in England', *Studies in Philology* vol. 26 (1929), 356–74, and S. Lamprecht 'The rôle of Descartes in seventeenth-century England', *Studies in the History of Ideas* vol. 3 (1935), 181–242. The best general survey of English physiology from Harvey to the decline of the Oxford tradition is Robert Frank, *Harvey and the Oxford Physiologists* (Berkeley, 1980). A useful survey of the theory of animal heat amongst the English physiologists is found in ch. 3 of E. Mendelsohn *Heat and Life: The Development of the Theory of Animal Heat* (Cambridge, Mass., 1964), 27–66.

2 Lamprecht, op. cit.

3 Descartes' cardiology is spelt out in detail in three places; the *Discours de la Méthode*, *Description de corp humain* and the correspondence with Plempius. Shorter discussions are found in *L'Homme* and the *Passions* and in other parts of his correspondence. Gary Hatfield ('Descartes' physiology and its relation to his psychology', in J. Cottingham, ed., *The Cambridge Companion to Descartes* (Cambridge, 1992) 335–70 points out that '[e]very one of Descartes' major works, those he published and those printed posthumously, contain some discussion of topics in physiology or in the physiology and psychology of the senses' (337).

4 See Galen, *On the Usefulness of the Parts of the Body,* tr. M.T. May (Ithaca, 1968), vol. i, 293–4 (VI, viii). For a useful summary of Galen's view see A.R. Hall, 'Studies on the History of the Cardiovascular System', *Bulletin of the History of Medicine*, vol. 34 (1960), 391–413.

5 Galen, notoriously, allowed for some transference of blood across the interventricular septum, see *Uses of Parts of the Body*, VI, xvii (323–4).

6 Following the Galenic tradition, Descartes did not consider the auricles to be parts of the heart. See for example *Discours*, AT vi. 48.

7 In traditional Galenic physiology the pulmonary artery was called the arterial vein (vena arteriosa) and the pulmonary vein was called the venous artery (arteria venosa). Descartes was aware of the misleading nature of this terminology, see *Discours*, AT vi. 47–9.

8 *Discours*, AT vi. 53, *Description*, AT xi. 236–7, and *L'Homme*, AT xi. 124.

9 *Discours*, AT vi. 50. Capillaries were first observed by Malpighi in 1661.

10 It should be noted that there is a recurrent confusion on this point in the literature. For example, Gweneth Whitteridge, in her important and influential book *William Harvey and the Circulation of the Blood* (London, 1971), misleadingly claims that for Descartes '[a]t the moment of systole these exhalations of blood are driven into the pulmonary artery' and again 'when the heart is in systole, the blood goes out through them [the arteries]' (151–2). She does give a correct account of Descartes' view, however, when she says, '[a]ccording to Descartes' theory, therefore, the heart and its ventricles are enlarged at the moment that the blood is expelled' (155). In fact, a similar confusion can be traced back to Descartes himself. In his first reply to Plempius he says, 'he [Harvey] clearly states . . . that the ventricles dilate at systole in order to take in blood, and contract at diastole in order to force the blood into the arteries', AT i. 527. While it apparently caused no concern for Plempius, James de Back asked 'Is it therefore fit for de Cartes to ascribe to Harvey which is against his mind?' (*Dissertatio de Corde*, Rotterdam, 1648: translated as *Discourse of the Heart, in The Anatomical Exercises of Dr. William Harvey* . . ., London, 1653, 110), and in our day Marjorie Grene finds this comment 'simply incredible', ('The Heart and Blood: Descartes, Plemp and Harvey', in S. Voss, ed., *Essays on the Philosophy and Science of René Descartes* (Oxford, 1993), 324–36: 328). In Descartes' case, the natural solution seems to be that he is using the traditional Galenic terminology in which the terms 'systole' and 'diastole' had all but lost their etymological roots. That is, they no longer referred strictly to the contractive and dilative phases of the heart's motion, but rather to the heart's lengthening and shortening. This appears to be confirmed by the sentence that precedes the one in question which says, 'I could easily see that . . . the ventricles grow larger at diastole and smaller at systole', AT i. 527.

11 *L'Homme*, AT xi. 123.

12 *Discours*, AT vi. 48.

13 *Description*, AT xi. 244.

14 Descartes to Plempius, 15 February 1638, AT i. 529. Descartes tells Plempius that there are two types of rarefaction gradual and instantaneous.

15 AT i. 530.

16 R. French, *William Harvey's Natural Philosophy* (Cambridge, 1994), 189–90. See Descartes to Regius, 24 May 1640, AT iii. 67.

17 AT ii. 69.

18 Descartes to Plempius, 15 February 1638, AT i. 529.

19 *Description*, AT xi. 242–3. As mentioned above, the Galenic view held that when the heart shortened and became hard its ventricles expanded.

20 *Description*, AT xi. 243. See also Descartes to Plempius, AT i. 527.

21 *Description*, AT xi. 243. See also Descartes to Plempius, AT i. 529.

22 *Description*, AT xi. 245. See also *Discours*, AT vi. 46–7 where Descartes says of the motion of the heart and arteries that 'being the first and most widespread movement that we observe in animals, it will enable us to decide how we ought to think about all the others'.

23 Descartes to Mersenne, 9 February 1639, AT ii. 501.

24 *L'Homme*, AT xi. 201–2. For other comparisons of *l'homme* with automata see *Discours*, AT vi. 55–6. See also Descartes to Beverwyck, 5 July 1643, 'all these operations are truly mechanical, as in fact the tests are mechanical by which it

is proved that there are various anastomoses of the veins and the arteries through which the blood flows from one to the other', quoted from G.A. Lindeboom, *Descartes and Medicine* (Amsterdam, 1979), 107. Lindeboom's Appendix II contains a translation of the whole correspondence between Descartes and both Beverwyck and Plempius.

25 *Description*, AT xi. 244. See also Descartes to Plempius, 15 February 1638, AT i. 523.

26 *L'Homme*, AT xi. 202. See also *Discours*, AT vi. 46.

27 For Descartes' resistance to a tripartite division of the soul see Descartes to Regius, May 1641, AT iii. 372–3. For an excellent discussion of the organic soul in the Renaissance see K. Park, 'The Organic Soul', in C.B. Schmitt and Q. Skinner, eds., *The Cambridge History of Renaissance Philosophy* (Cambridge, 1988), 464–84.

28 See, for example, Gary Hatfield, 'Descartes' physiology and its relation to his psychology', in *The Cambridge Companion to Descartes*, op. cit., 335–70: 343–4.

29 *Discours*, AT vi. 50.

30 Here I disagree with Gilson who claims of Descartes' attitude to Harvey's view that 'he never doubted that it was coherent and able to render an account of the phenomena; on the contrary he saw in it one of those cases where two different explications render an account of the same phenomenon in an equally satisfactory manner' (*Études sur le role de la pensée Médiévale dans la formation du système Cartésien* (Paris, 1930), 94). I do not believe that Descartes advanced his explanation of the movement of the heart in the light of his thesis about the underdetermination of corpuscular explanations. Descartes' attitude to his explanation of the movement of the heart poses problems for his attitude to certainty within his mechanism as a whole and is therefore related to his philosophy of science. My disagreement with Gilson is therefore deeper than merely a psychological claim, but it is beyond the scope of this paper to explore this issue here. For Descartes on underdetermination, see *Principles of Philosophy*, 4, §204, AT viii-A. 327.

31 Descartes to Plempius, 15 February 1638, AT i. 529.

32 For recent discussions of the Harvey/Descartes controversy see D. Clarke, *Occult Powers and Hypotheses* (Oxford, 1989); M. Greene, 'The Heart and Blood: Descartes, Plemp and Harvey', in S. Voss, ed., *Essays on the Philosophy and Science of René Descartes* (Oxford, 1993), 324–36; G. Gorham, 'Mind–Body Dualism and the Harvey-Descartes Controversy', *Journal of the History of Ideas*, vol. 55 (1994) 211–34; and R. French, *William Harvey's Natural Philosophy* (Cambridge, 1994), ch. 8.

33 This epithet is Samuel Hartlib's, see Hartlib to Boyle in *The Works of the Honourable Robert Boyle*, ed. T. Birch, (6 vols, reprint edn., Hildesheim, 1965), vi. 92.

34 *Second Essay to Jean Riolan*, in *The Circulation of the Blood and other Writings*, tr. K.J. Franklin (London, 1990). Harvey possibly has Descartes in mind in his earlier discussion of spirits. See C. Webster, 'Henry Power's Experimental Philosophy', *Ambix* vol. 3 (1967), 150–78: 173.

35 Descartes' account of the movement of the heart was dismissed as absurd by Riolan. See Gilson, op. cit., 96.

36 Plempius published a version of his correspondence with Descartes in summary form in 1638 in his *Fundamenta medicinae* (Louvain) and in full in 1644 in the second edition of that work. Beverwyck also published the correspondence in his *Epistolicae Quaestiones* of 1644.

37 *Second Essay to Jean Riolan*, 137.

38 As de Back puts it '[t]he same time in which one says there is a Systole, the other sayes there is a Diastole', *Discourse of the Heart*, 110.

39 *Second Essay to Jean Riolan*, 138.

40 Ibid.
41 This point is made more clearly in the *Second Essay to Jean Riolan*, 115.
42 *Second Essay to Jean Riolan*, 131.
43 *Exercitatio anatomica de motu cordis et sanguinis in animalibus* (Frankfurt, 1628), 30.
44 W. Pagel, *William Harvey's Biological Ideas* (New York, 1967), 265.
45 The work was entitled *The Anatomical Exercises of Dr. William Harvey* ... (London, 1653).
46 Descartes' view is outlined in de Back's *Discourse of the Heart* in section III, ch. 1, 75–76 and critically evaluated in chapter 2, 82–9, and in the 'Addition', 109–23.
47 G. Gorham, op. cit., 218–23.
48 Pace J. Passmore 'William Harvey and the Philosophy of Science', *Australasian Journal of Philosophy*, vol. 36 (1958), 85–94, and R. Toellner, 'The controversy between Descartes and Harvey regarding the nature of cardiac motions', in A.G. Debus, ed., *Science, Medicine and Society in the Renaissance: Essays to honour Walter Pagel*, vol. 2 (New York, 1972), 73–89, and 'Logical and psychological aspects of the discovery of the circulation of the blood', in M.D. Grmek, R.S. Cohen and G. Cimino, eds., *On Scientific Discovery* (Dordrecht, 1980), 239–59. While Passmore does not explicitly construe the controversy as one between rationalism and empiricism, he claims of Harvey's view that '[h]ere, then, is a confident empiricism at the opposite pole from Descartes' depreciation of sensory observation', (92) and that 'the dispute between Descartes and Harvey ... is a notable example of a head-on collision between two opposing philosophies of science', (93). Echoes of this rationalist/empiricist dichotomy still persist in the literature on the dispute between Harvey and Descartes. For instance, Roger French claims, 'Harvey's first principle of procedure was a mode of observation, comparison and experiment ... in contrast these modes are generally held to have a place in Descartes' natural philosophy only when the deductive descent from first principles ramified to the extent that the mind was unable to choose on a priori grounds the course that nature had chosen' (op. cit., 186). For further discussion of this issue see M. Grene, op. cit., 333ff.
49 R. Frank, op. cit., 33–4.
50 It should be noted that J. Primrose had attacked Regius' version of Descartes' cardiology as early as 1640 in his *Animadversiones in theses, quas pro circulatione sanguinis in Academia Ultrajacensi D Henricus le Roy* (Leiden, 1640) and again in 1644 in his *Antidotum adversus Henrici Regii Ultraiactensis medicinae professoris venenatam Spongiam* (Leiden, 1644). But neither of these works was conceived as an explicit attack on Descartes' account of the movement of the heart. For a discussion of the exchange between Regius and Primrose see R. French, op. cit., 210–14.
51 N. Malcolm, ed., *The Correspondence of Thomas Hobbes* (2 vols., Oxford, 1994), i. 51.
52 See *Two Treatises: Of Bodies and On Man's Soul* (Paris, 1644), 233–4.
53 Ibid., 233.
54 Ibid., 235. See *De Motu Cordis*, 26–7.
55 Digby, *Two Treatises*, 236.
56 Ibid., 236.
57 Contra Harvey, *De Motu Cordis*, 21, '[a]lso untrue is the common belief that the heart draws any blood into the ventricles by any movement of its own or by its distension'.
58 *Two Treatises*, 238
59 Ibid., 235.
60 William Petty also combined Harvean and Cartesian elements in his cardiology. See R. Frank, op. cit., 102.

61 *The Works of Sir Thomas Browne, vol. 4,* ed. G. Keynes (London, 1928), 255.
62 Ibid., 260.
63 C. Webster (op. cit., 155, n. 23) points out that both of these books were in Power's library.
64 T. Browne, op. cit., 261.
65 Of course More was soon to become disillusioned with Descartes' views, but as Webster points out his period of enthusiastic endorsement coincides with Power's earliest references to the French philosopher.
66 Power, *Circulatio Sanguinis Inventio Harveiana* (1652), printed in F.J. Cole, ed., 'Henry Power on the circulation of the blood', *Journal of the History of Medicine and Allied Sciences,* vol. 12 (1957), 291–324: 297, cf. 310.
67 Ibid., 299 and 316.
68 Ibid., 299.
69 Ibid., 300. Webster goes so far as to claim that Power's *Circulatio* 'was one of the most detailed and interesting of the early English apologies for Harvey's doctrine' (op. cit., 155). In fact, at some points Power seems to be summarising Harvey's *De Motu Cordis.* Compare for instance the discussion of the simple experiments to prove the unidirectional nature of the flow of blood in the veins in Power, *Circulatio,* 308, and Harvey, *De Motu Cordis,* 66–7.
70 Webster (op. cit., 159) points out that Power published a work in 1661 whose short title is *Mercurial Experiments,* but that he has not been able to find a copy.
71 The Preface to *Experimental Philosophy* is reprinted in M.B. Hall *Nature and Nature's Laws* (London, 1970), 122–6.
72 Power *Experimental Philosophy* (London, 1664), 66 and Harvey's *De Motu Cordis,* 86; note that Harvey includes the lungs as well.
73 Webster, op. cit., 173.
74 *Analogia Physico-Chymica* (1666), Sloane MS 496, 5, British Museum, 5.
75 Power says that the animal spirits are 'the purest, subtlest, and most volatile particles and activist Atoms of the bloud, which by continual pulsation of the Heart are carried with the bloud by the carotidal Arteries up into the Brain . . .', *Experimental Philosophy,* 66.
76 Ibid., 68.
77 Webster, op. cit., 173.
78 'Sententia Cartesii de motu cordis non est veritati consentanea', Sloane MS 3309, fols. 141r-142v. I would like to thank Guido Giglioni for drawing my attention to these folios and for providing me with a transcription.
79 *The Immortality of the Soul,* ed., A. Jacob (Dordrecht, 1987), 134, 135.
80 R. Cudworth, *The True Intellectual System of the Universe* (reprint. edn., 3 vols., Bristol, 1995), i. 248.
81 See for instance his *History of Fluidity and Firmness,* in *Works,* op. cit., i. 434ff.
82 Boyle's response to the Cambridge Platonists is found in his *A Free Enquiry Into the Vulgarly Receiv'd Notion of Nature; Made in an Essay, Address'd to a Friend,* 1686, *Works,* v. 158ff.
83 *Works* ii. 69.
84 Ibid.
85 Descartes to Plempius, AT i. 530.
86 Webster, op. cit., 168. For Le Grand's acceptance of Cartesian cardiology see his *An Entire Body of Philosophy According to the Principles of the Famous Renate Des Cartes,* tr. R. Blome (London, 1694), Part VIII, ch. 6, 275–6.
87 La Forge says, 'I do not think that we are able to assign another cause to explain the manner by which the beating of the heart and arteries and this great change that we noted between the venous and arterial blood are intelligible than the ebullition or fermentation produced by the rest of the blood which remains in the little cavities of the heart', *L'Homme de René Descartes . . .*

avec les remarques de Lois de la Forge (Paris, 1677), 166–7. Though it should be noted that La Forge is guilty of the sort of confusion about cardiac motion mentioned in note 10 above. He completely misunderstands the Harvean view when he says that 'Harvey was wrong when he believed that the blood leaves the heart when it is elongated', ibid., 174. Rohault defends the Cartesian account of the heart's movement in his *Traité de Physique* of 1671, Part IV, ch. 12, which became a popular text in Cambridge. For an important French critique of the Cartesian view see the 'Quatorzième conférence' of Jean Baptiste Denis in the Supplement of the *Journal des Sçavants*, 1 Feb 1674, 249–53.

88 *De Respiratione*, ed. L. Dobbin (Edinburgh, 1946), 18–19.

89 Lower, *Tractatus de Corde* (1669), iv–v.

90 Ibid., 60–1.

91 Ibid., 61–2.

92 Ibid., 62–5.

93 Ibid., 74. See also, 'I am so far from believing the movement of the blood to be dependent on any heating (*accensione*) of it within the heart, that I do not think it owes any of its heat to this organ', ibid., 71.

94 *Tractatus De Corde*, 166.

95 See Glisson's ' "Doctrina de circulatione sanguinis haud immutat antiquam medendi methodum", an unpublished manuscript (1662) by Francis Glisson on implications of Harvey's physiology', ed. J.N. Boss, *Physis* (1978), 309–36.

96 See Boyle's *Some Considerations touching the Usefulness of Experimentall Naturall Philosophy*, Part II, section I, essay V, in *Works*, ii. 113ff. For a detailed study of Boyle's attitude to Galenism, see M. Hunter, 'Boyle versus the Galenists: a suppressed critique of seventeenth-century medical practice and its significance', *Medical History*, vol. 41 (1997), 322–61.

97 Lamprecht, op. cit., 199ff.

98 See T.M. Brown, 'From mechanism to vitalism in eighteenth-century English physiology', *Journal of the History of Biology*, vol. 7 (1974), 179–216.

Part IV

Imagination and representation

19 Cartesian imagination and perspectival art

Betsy Newell Decyk

> Like perspectives, which rightly gazed upon
> Show nothing but confusion – eyed awry
> Distinguish form.
>
> Shakespeare, *Richard II*, ii, 18–20 (1597)

Introduction

Cartesian scholarship has, in recent years, enlarged and enriched our understanding of Descartes. It has, first of all, taken a more comprehensive view of the Cartesian corpus, seeing Descartes as not just the philosopher of the *Mediationes*, but also as a natural philosopher, that is, the philosopher-mathematician-scientist who also authored the *Regulae*, the *Dioptrique*, the *Géometrie* and the *Principia*. Second, it has provided us with more of the context surrounding Descartes; it has looked more carefully into both the scholastic texts and contemporary mathematical and scientific controversies. In the fifteenth to the seventeenth centuries, however, a whole genre of optical problems were tackled not just by natural philosophers, but also by artists like Da Vinci, Dürer, and Niceron. In this paper I begin to connect the history of philosophy with the history of art. In particular, I will show that understanding the artistic experiments and achievements in optics in the fifteenth to the seventeenth centuries opens new lines of scholarship that enhance even further our understanding of Descartes' natural philosophy and, specifically, the role of imagination in his natural philosophy.

Puzzling comments about imagination

In the *Meditationes* Descartes introduces the technique of methodic doubt to gain knowledge. In the First Meditation he systematically questions both sense experience and the imagination in order to reveal in later Meditations what can be known clearly and distinctly about the soul and God. Since philosophers have concentrated on the *Meditationes*, they have assumed that a negative view of the imagination and sense-experience carries through his other writings as well. It is therefore surprising and confusing to find passages which belie this standard view. In the *Regulae*, which predates the *Meditationes*, we find Descartes writing:

> Within ourselves we are aware that, while it is the intellect alone that is capable of knowledge, it can be *helped* or hindered by three other faculties, viz. imagination, sense-perception and memory. We must therefore look at these faculties in turn, to see in what respect each of them could be a hindrance, so that we may be on our guard, and in what respect an *asset*, so that we may make full use of their resources.[1]

Or again, in Rule 12:

> As for ourselves, there are only four faculties which we can use for this purpose [gaining knowledge of things], viz. intellect, imagination, sense-perception and memory. It is of course only the intellect that is capable of perceiving the truth, but it has to be assisted by imagination, sense perception and memory if we are not to omit anything which lies within our power.[2]

and:

> So we can conclude with certainty that when the intellect is concerned with matters in which there is nothing corporeal or similar to the corporeal, it cannot receive any help from these faculties; on the contrary, if it is not to be hampered by them, the senses must be kept back and the imagination must, as far as possible, be divested of every distinct impression. If, however, the intellect proposes to examine something which can be referred to the body, the idea of that thing must be formed as distinctly as possible in the imagination. In order to do this properly, the thing itself which this idea is to represent should be displayed to the external senses.[3]

Furthermore, this kind of comment cannot be dismissed as merely ‘early Descartes’, because we find similar remarks in his later works as well. For example, in his correspondence with Princess Elizabeth, Descartes writes:

> First of all, then, I discern a great difference in these three sorts of notions, in that the soul cannot be conceived other than by the pure understanding; body (that is, extension, figure and motion) may be known by the understanding alone, but can be known much better by the understanding when it is aided by the imagination. Finally the notions which apply to the union of the soul and body can be known only obscurely by the understanding alone, and no better by the understanding aided by the imagination; but they can be known very clearly by the senses.[4]

Thus, we begin with a puzzle. In what ways can imagination help the intellect? In what ways does imagination give us a better understanding of body? If we suppose that the methodic doubt of the *Meditationes* is meant to show us ways in which imagination can be a hindrance 'so that we may be on our guard',[5] perhaps other Cartesian texts show us the ways imagination can be an asset, 'so that we may make full use of . . . [it]'.[6]

Imagination and the mathematization of experience

For Descartes, both perception and imagination are modes of thought concerned with corporeal nature, but imagination is described as the mode of thought concerned with corporeal nature in general, which is Descartes' way of referring to mathematics. One feature of imagination, according to Descartes, is its ability to provide a mathematisation of sense experience.

That Descartes locates this ability to mathematise experience in the imagination is obvious in the *Regulae*. Rule 13, for instance, directs us to 'abstract it [the problem] from every superfluous conception, reduce it to its simplest terms, and by means of enumeration, divide it up into the smallest possible parts';[7] in Rule 14, Descartes writes that 'the problem should be re-expressed in terms of the real extension of bodies and should be pictured in our imagination entirely by means of bare figures',[8] and in the explanation of Rule 14 it becomes clear that the result of this method is a mathematical description of the problem:

> Consequently, when the terms of a problem have been abstracted from every subject in accordance with the preceding Rule, then we understand that all we have to deal with here are magnitudes in general.[9]

In the *Dioptrique*, Descartes does not explicitly explain the imagination, but if we look to the uses he makes of it, we see that it is often involved in the mathematisation of experience. We are directed to imagine the motion of a tennis ball (and by analogy, a ray of light) as having both a vertical and a horizontal component:

> Moreover, it must be noted that not only the determination to move in a certain direction but also the motion itself, and in general any sort of quantity, can be divided into all the parts of which we can imagine that it is composed. And we can easily imagine that the determination of the ball to move from A towards B is composed of two others.[10]

In other places in the *Dioptrique* we are directed to imagine the rays of light as being 'exactly straight when they pass through a single transparent body which is uniform throughout',[11] and deflected by curved surfaces as they would be if the surface were flat at that point.[12] Both of these imaginings make the computation of the motion easier.

Finally, there is the famous passage in the *Dioptrique* about how how we assess distance.[13] On this topic Descartes makes four different observations. The 'seeing' of distance depends first on the shape of the eye, second, on our binocular vision and/or our ability to move our eyes, third, on the combination of the distinctness of the image and the strength of the light, and fourth, on our familiarity with the object from other contexts. The first of these, the adjustment of eye-shape, happens for the most part automatically, without reflection. The second, however, involves the imagination and provides us with a knowledge of distance, 'as if by a natural geometry'. Descartes explains this method of assessing distance by giving an analogy of a blind man assessing distance by means of two sticks. A and C are the right and left hands, respectively, that are holding the sticks and E is the place where the sticks, cross each other.

> In the second place, we know distance by the relation of the eyes to one another. [See Figure 19.1] Our blind man holding the two sticks AE and CE (whose length I assume he does not know) and knowing only the distance between his two hands A and C and the size of the angles ACE and CAE, can tell from this knowledge, as if by a natural geometry, where the point E is. And similarly [see Figure 21.2 (p. 510)] when our two eyes RST and rst are turned towards point X, the length of the line Ss and the size of the two angles XSs and XsS enable us to know where the point X is. We can do the same thing also with the aid of one eye, by changing its position. Thus, if we keep it turned towards X and place it first at point S and immediately afterwards at point s, this will be enough to make our imagination contain the magnitude of the line Ss together with that of the two angles XSs and XsS, and thus enable us to perceive the distance from point X. And this is done by a mental act, which though a very simple act of the imagina-

Figure 19.1

> tion, involves a kind of reasoning quite similar to that used by surveyors when they measure inaccessible places by means of the two different vantage points.[14]

We will revisit this specific quotation again in the next section and suggest a way of understanding it. Two points can be emphasised here, however. One point to notice is the comparison that Descartes makes between this act of assessing distance with surveying. The second point to notice is that he describes this act as a 'very simple act of the imagination'.

It is clear from these passages in the *Regulae* and the *Dioptrique* that Descartes relies upon the imagination to transform experience into magnitudes. This seems to be a (perhaps the) positive contribution of the imagination. Second, it would be disastrous for his scientific programme if the imagination in this function could not be trusted at least in certain cases or in certain ways. In the next section we will begin to build an extended analogy with perspectival art to explain this role of the imagination.

Perspective

In the seventeenth century, optical puzzles engaged not just the natural philosophers, like Descartes, Kepler and Galileo,[15] but also artists developing techniques of perspective, mathematicians, mapmakers and others.[16] This is obviously a complex set of interrelationships, and this paper only begins to explore this larger context, primarily with respect to art.

Western Medieval art is often described as 'flat'. What this means is that there is little, or no, perspective, or depth, to the picture. If the background of the painting is uniform, for example, gold leaf, depth cannot be created by changes in tone or shadows. Often the depth we do experience in a medieval painting, if we experience depth at all, is created by occlusion, the overlapping of figures.

One of the great contributions of the Renaissance to art was the development of perspective: the art of making a flat surface appear three dimensional. This illusion of depth in a picture is created not only by occlusion, but also by various systematic changes within the picture.[17] The work of Jan Vredeman de Vries (1609–10) (see Figure 19.2) illustrates the perspective of vaulted interiors. Here the gold leaf background has been replaced by a realistic room. Furthermore, there is a single central perspective point which unifies the depth of the picture. The series of vaults and columns and their accompanying spaces 'recede' into the background. In this picture the appearance of depth is created in a threefold manner: first, by occlusion – columns overlap the background and columns overlap columns; second, by the alternating of light and dark tone, or shadowing, in the picture; finally, by changes in the shapes and sizes of the columns and vaults. The insight of perspective is that the illusion of depth can be created by systematic changes in all these ways.

Figure 19.2 Jan Vredeman de Vries: Vaulted interior.

Many names are mentioned in the development of perspective in the Renaissance: Giotto, Brunelleschi, Massaccio and others. The first person to write specifically on linear perspective in painting, however, was Alberti, and it is clear that he understood the systematic changes in sizes and shapes needed to create the illusion of depth as a geometrical system. In fact, he advised that a painter be

> as learned as possible in the liberal arts, but first of all I desire that he know geometry. . . . Our instruction in which all the perfect absolute art of painting is explained will be easily understood by a geometrician, but one who is ignorant in geometry will not understand these or any other rules of painting. Therefore, I assert that it is necessary for the painter to learn geometry.[18]

The important geometrical theorem for linear perspective is that if a straight line parallel to one side of a triangle (e.g. the base) cuts the other two sides of the triangle, then the smaller triangle created is proportional to the larger triangle. Vision is then likened to a pyramid, and different distances are likened to planes which cut the pyramid. When they cut the pyramid parallel to the base of the pyramid, they create proportional triangles. This allows for a precise mathematical rendering of objects relative to each other.[19] Alberti believed, too optimistically, that a similar geometry of proportional triangles applied also to shadows and colours.[20]

Spencer has argued that Alberti's understanding of perspective came originally from his experience in surveying; he notes that in the years 1431–4 Alberti composed *Descriptio urbis Romae,* which detailed a method of surveying Rome, together with tables of sightings for various Roman monuments, and a description of a sighting instrument he designed for the purpose which was

> a bronze disc mounted parallel to the surface of the earth and divided on the circumference into 48 degrees. At the centre, a metal or wooden ruler, divided into 50 degrees, is pivoted. This can be used to parallel the line of sight of the monument, and at right angles to the sight to obtain the proportionate width. When the ruler is placed at right angles to the line of sight it becomes possible to compute the distance of the object given its width – or its actual width given the distance – by means of the similarity of triangles. With such an instrument the proportionate quantities vary according to the distance of the object, a statement which frequently occurs in *Della Pictura.*[21]

Spencer continues the note by explaining in more detail how a precise calculation (not just a proportional one) can be accomplished by this method.

While the origins of perspective are indistinct, it is clear that early experimenters with perspective developed various techniques and tools to help the painter understand and create the illusion of depth in a painting. Brunelleschi may have been the first to use a camera obscura[22]; Da Vinci certainly experimented with one.[23] Another common technique was to imagine, or actually place, a panel of glass as the plane parallel to the base of the visual pyramid.[24] Furthermore, Alberti, Da Vinci and Dürer all suggested placing a net or veil in front of the scene to be painted. The veil or net served as a grid to correctly place and proportion the size and shape of the objects to be pictured.

Pictures in Dürer's *Underweysung der Messung* (1525) help us understand two of the devices used in perspectival drawing. In one of these (Figure 19.3), drawing in perspective is represented as a 'special kind of seeing'. In this picture a person is using a glass panel and a special eyepiece in order to draw in perspective. The panel forms the perspective plane for the picture. The eye piece is apparently adjustable, and changes the 'horizon' in the picture plane. In addition, the glass may have a grid on it, but we cannot tell from this picture. A second picture from Dürer's book

Figure 19.3 Dürer: Glass panel/eyepiece picture, from *Underweysung der Messung* (1525).

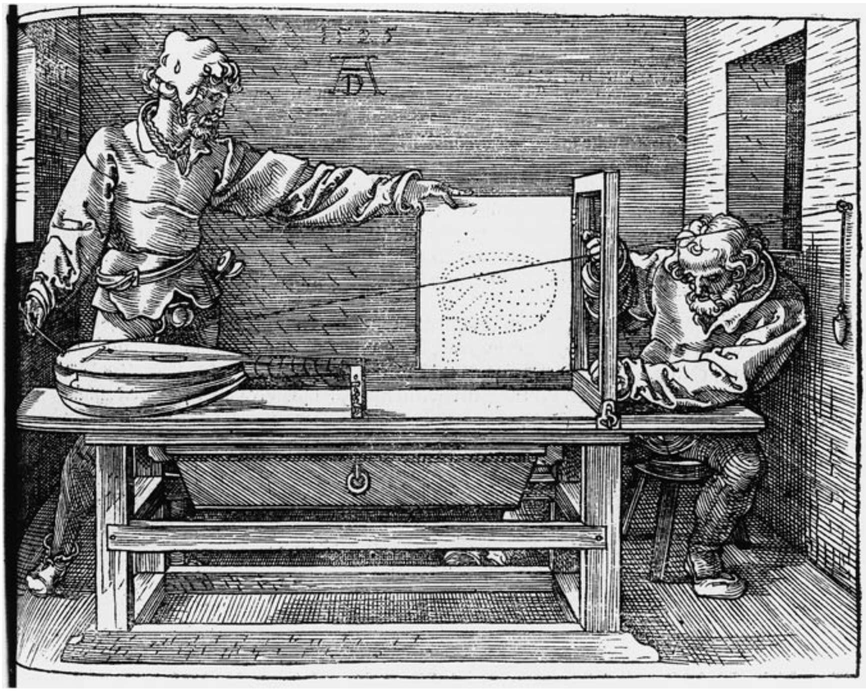

Figure 19.4 Dürer: The string and the lute, from *Underweysung der Messung* (1525).

(Figure 19.4) adds to our understanding of the process of picturing in perspective. In this picture, strings are used to measure how the lute should be drawn in a plane at right angles to it. The system of strings and points allows the painter to recreate exactly the relationships of size and shape of the lute as they appear the (new) picture plane.

Understanding how perspective in a two-dimensional painting is created by measuring angles or by overlaying a grid on a scene that defines mathematical relationships between the objects in the picture provides a possible analogy for interpreting Descartes' comments about the imagination. As we have seen, one of the helpful functions of the imagination is that it provides a way of ordering experience so that one can analyze it mathematically. Suppose that for Descartes the imagination acts like the glass panel of the perspectivists. It would allow for the placement of objects in a comparative framework and one could find an object in relationship to other objects. If we suppose further that the imagination is like a grid device (a net or veil or cross lines on the glass) or the device with the measuring strings, it would provide the ability to mathematise these comparative relationships. In this analogy, sensation does not enter the mind with its mathematical relationships already marked on it; these relationships are 'marked', as it were, by an overlay of imagination on the experience.

Further evidence that Descartes thinks of this mathematisation by the imagination as an overlay on corporeal objects appears in passages throughout the Cartesian corpus. In the *Regulae* Descartes chides the mathematicians for abstracting mathematical concepts away from objects,[25] and in the *Principia* he asserts that shape, motion, duration and number are modes of things. The emphasis is usually put on *modes* of things; but Descartes' point is that they are modes *of things*. 'Shape is unintelligible except in an extended thing,'[26] he writes, and later: 'similarly we should not regard order or number as anything separate from the things which are ordered and numbered'.[27]

In Descartes' explanation of the assessment of distance by means of binocular vision and/or the ability to move our eye from one position to another, the distance of the object is based on the distance between the eyes (the base of the triangle) and the sighting angles (alternatively, for the blind person the distance is based on the distance between the hands and the hand-angles). Descartes specifically says that the mental act involved, 'though a very simple act of the imagination, involves a kind of reasoning quite similar to that used by surveyors when they measure inaccessible places by means of the two different vantage points'.[28] For Alberti, the distance to a point can be calculated if the width and the angles are known, but the calculation relies on the mediation of the sighting device which provides the measurements. It makes sense, then, to liken Descartes' imagination to a similar device which provides a way to create triangles, compare positions and provide measurements – the mathematisation of the experience. The link between surveying and perspective that Spencer attributes to Alberti strengthens the analogy by not only underscoring the common geometrical basis of the two activities, but also their historical interconnection.

Independence of the image from the object

Perspective begins to free the image from the object. The distinction between the object and how it is represented was clearly of concern to artists trying to develop perspectival painting. It worried Leonardo Da Vinci, for example, and in paragraph 82 of Libro A (c. 1508). Da Vinci attempts to explain 'why, when measuring a face and then painting it life size, it will appear larger than nature'.[29] If we saw an object by means of an intentional form which the object gave off and which exactly resembled it, then there should not be a mismatch between the object and our perception of it. The theory of intentional forms could not answer Leonardo's question, and had to be abandoned.

Descartes, too, knows that the image does not need to resemble the object it represents. Descartes opens *Le Monde* by making this point with respect to light:

> The subject that I propose to treat of in this treatise is light, and the first point I want to draw to your attention is that there may be a difference between the sensation we have of light (i.e. the idea of light which is formed in our imagination by the mediation of our eyes) and what it is in the objects that produces this sensation within us (i.e. what it is in a flame or the sun that we call by the name 'light'). For although everyone is commonly convinced that the ideas that we have in our mind are wholly similar to the objects from which they proceed, nevertheless I cannot see any reason that assures us that this is so. On the contrary, I note many observations which should make us doubt it.[30]

In Part I of the *Dioptrique*, Descartes extends this claim from the case of light in general to colours:

> Hence you will have reason to conclude that there is no need to suppose that something material passes from objects to our eyes to make us see colours and light, or even that there is something in the objects which resembles the ideas of sensations that we have of them.[31]

In these passages Descartes is rejecting the scholastic theory of intentional forms – the idea that objects transmit to the soul material forms which exactly resemble the objects. Descartes himself uses the example of engravings and perspective to make his point in Part IV of the *Dioptrique* clearer. Descartes continues:

> It is enough that the image resembles its object in a few respects. Indeed the perfection of the image often depends on its not resembling its object as much as it might. You can see this in the case of engravings: consisting of simply a little ink placed here and there on a piece of paper, they represent to us forests, towns, people and even battles and storms; and although they make us think of countless different qualities in these objects, it is only in respect of shape that there is any real resemblance. And even this resemblance is very imperfect since engravings represent to us bodies of varying relief and depth on a surface which is entirely flat. Moreover, in accordance with the rules of perspective they [engravings] often represent circles by ovals better than by other circles, squares by rhombuses better than by other squares, and similarly for other shapes. Thus it often happens that in order to be more perfect as an image and to represent an object better, an engraving ought not to resemble it. Now we must think of the images formed in our brain in just the same way, and note that the problem is to know simply how they can enable the soul to have sensory perceptions of all the various qualities of the objects to which they correspond – not to know how they can resemble these objects.[32]

We can illustrate Descartes' point with engravings from Jan Vredeman de Vries' book, *Perspective*, published in 1604–5, and possibly known to Descartes, as it was dedicated to Maurice of Nassau, whose service Descartes was in during 1617–9. The first (Figure 19.5) shows that circles drawn in perspective are no longer circles, but ovals, because one end is 'pinched in' to make it look as if the shape 'recedes' into the background. Similarly, squares drawn in perspective are no longer squares (Figure 19.6).

In most of the pictures considered so far there is a single, central perspective point and the illusion of depth has been created on a flat surface. However, the same sort of techniques, using proportionality and mathematisation, were effective for creating a painting of depth on curved surfaces. Around 1504, for example, Da Vinci experimented with mirrors and gave a geometrical explanation of the optics involved; in 1524 Parmigianino created his famous Self-Portrait in a concave mirror. Similar principles were used to create illusions on other curved surfaces like domes. In all of these cases, there is a single, central perspective point. What creates the illusion of depth are the proportional changes of size, shape and tone. Changes in tone and colour are systematic and proportional, although not highly mathematical or easily mathematisable. The principles of proportionality for size and shape involved a different mathematics on curved surfaces – circular grids rather than rectilinear ones – but they were no less mathematical.

Artistic 'play'

In the last of his notes on linear perspective Da Vinci makes a distinction between natural and artificial perspective. While his explanation is sketchy, natural perspective seems to be the perspective which we are familiar from our ordinary experience. In natural perspective, objects of equal size look smaller when they are more remote and larger when they are nearer. There is a single standpoint for this natural perspective. In contrast, artificial perspective is created by artists. In this perspective a smaller object can appear larger than it would in natural perspective because the object is viewed from an angle.[33]

By the sixteenth and early seventeenth century Western European artists had mastered many of the principles of natural perspective. Now they were beginning to question them, extend them, and 'play' with them. Many of these variations are classed together as anamorphic art. Anamorphic art, however, is not just one thing. There are different kinds of anamorphoses.

One kind of artistic 'play', elongated anamorphosis, is reminiscent of Da Vinci's artificial perspective. In this case the artist intentionally shifts the viewing point away from the centre. One example of this picture is a portrait of Edward VI done in 1546. Viewed from the front (Figure 19.7a)

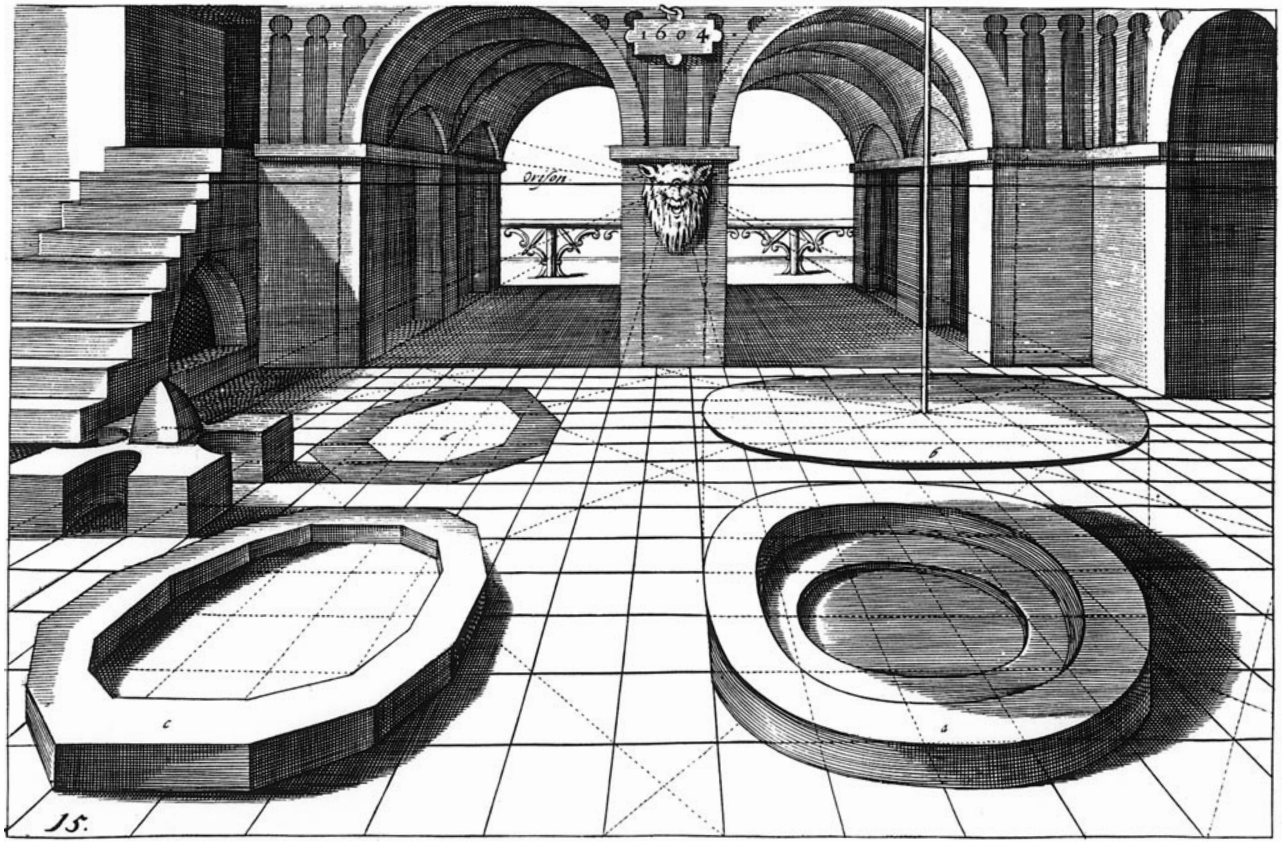

Figure 19.5 Jan Vredeman de Vries: Circles in Perspective.

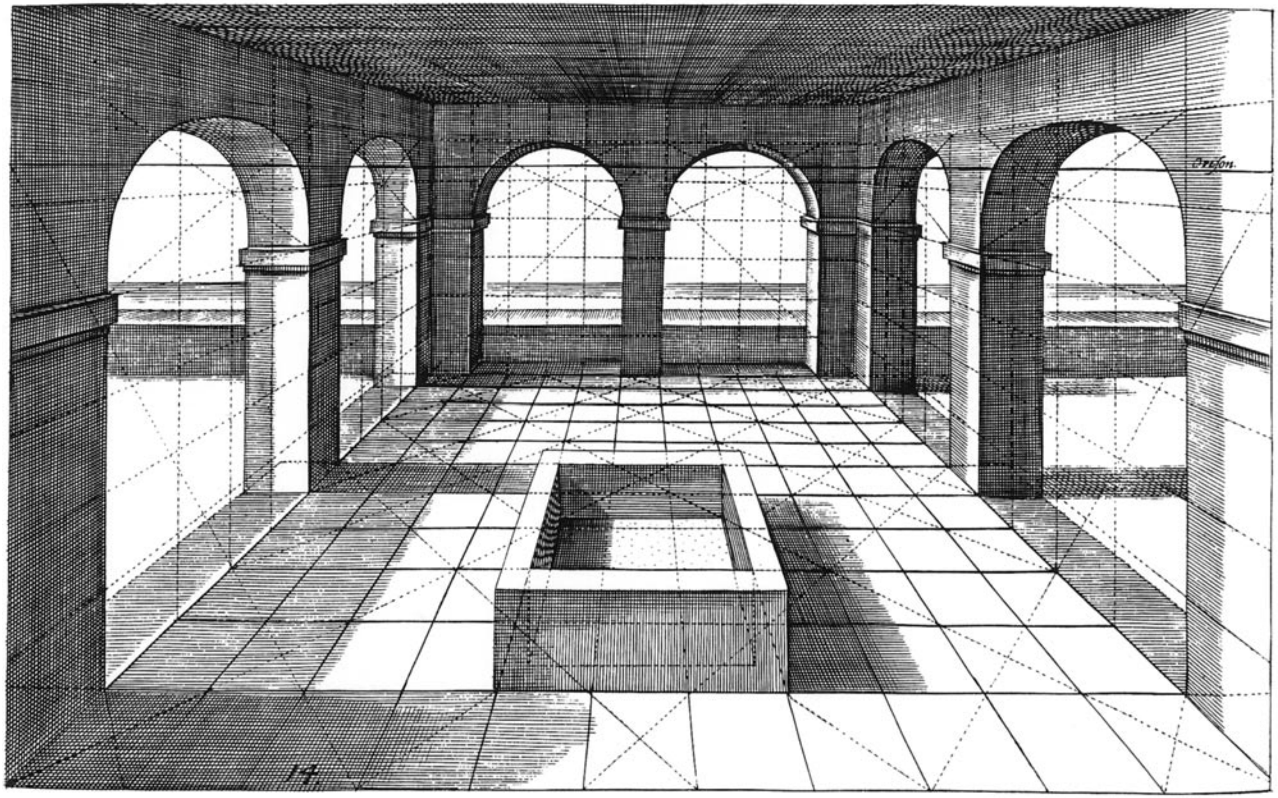

Figure 19.6 Jan Vredeman de Vries: Squares in Perspective.

Figure 19.7a William Scrots, *Edward VI* (1546): anamorphosis, from the front.

Figure 19.7b From the side.

the image is distorted, but viewed from a hole in the frame (Figure 19.7b), the distortion disappears.

This kind of anamorphic art does have a single perspective point, but it is not central. Furthermore, the distortion and the correction are not viewed from the same place or at the same time. The viewer has to shift position to find it. The distortion, which is experienced when viewing the picture directly, disappears when the picture is 'eyed awry'.

Another kind of artistic 'play' has a single, *central* perspective point, but that point has to be supplied by placing a polished surface, often a cylinder or a cone, on the picture. Until the perspective point is supplied, the picture is confused. There seems to be something there, but what? This kind of anamorphosis, called, mirror or catoptric anamorphosis, is believed to have been introduced in France in the 1620s by Vouet.[34]

Jean-François Niceron was a master of mirror anamorphoses and the mathematics on which they were based. In his book *La Perspective curieuse* (1638), Niceron illustrated the mathematical grids for making cylinder (Figure 19.8), cone (Figure 19.9), and pyramid (Figure 19.10) anamorphic pictures. Apparently cones were particularly popular anamorphic devices because the subject matter of the picture could be completely hidden until the cone was in place.[35]

The important point here is that both elongated and catoptric anamorphosis involve an underlying geometry. The geometry of

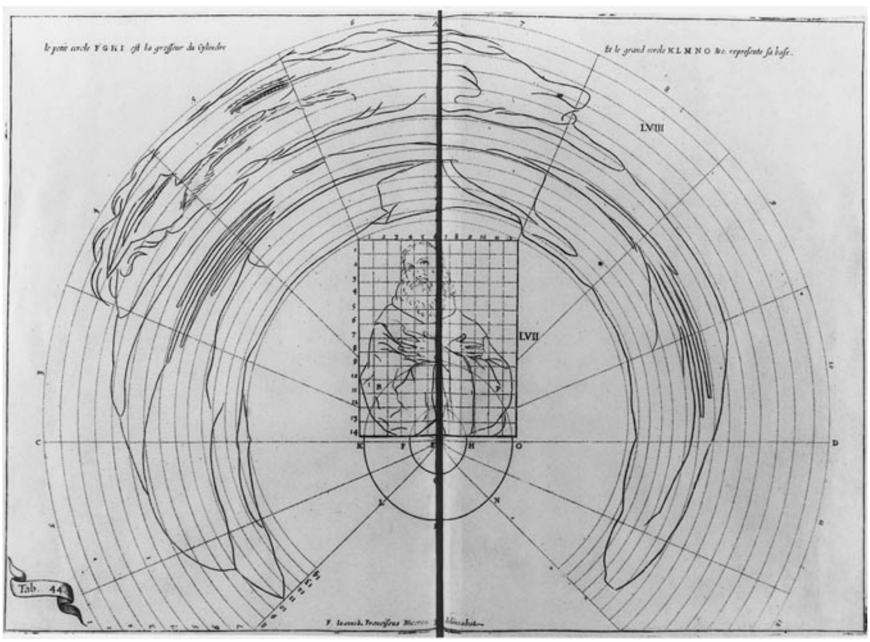

Figure 19.8 J.F. Nicéron, cylinder, from *La Perspective curieuse* (1638).

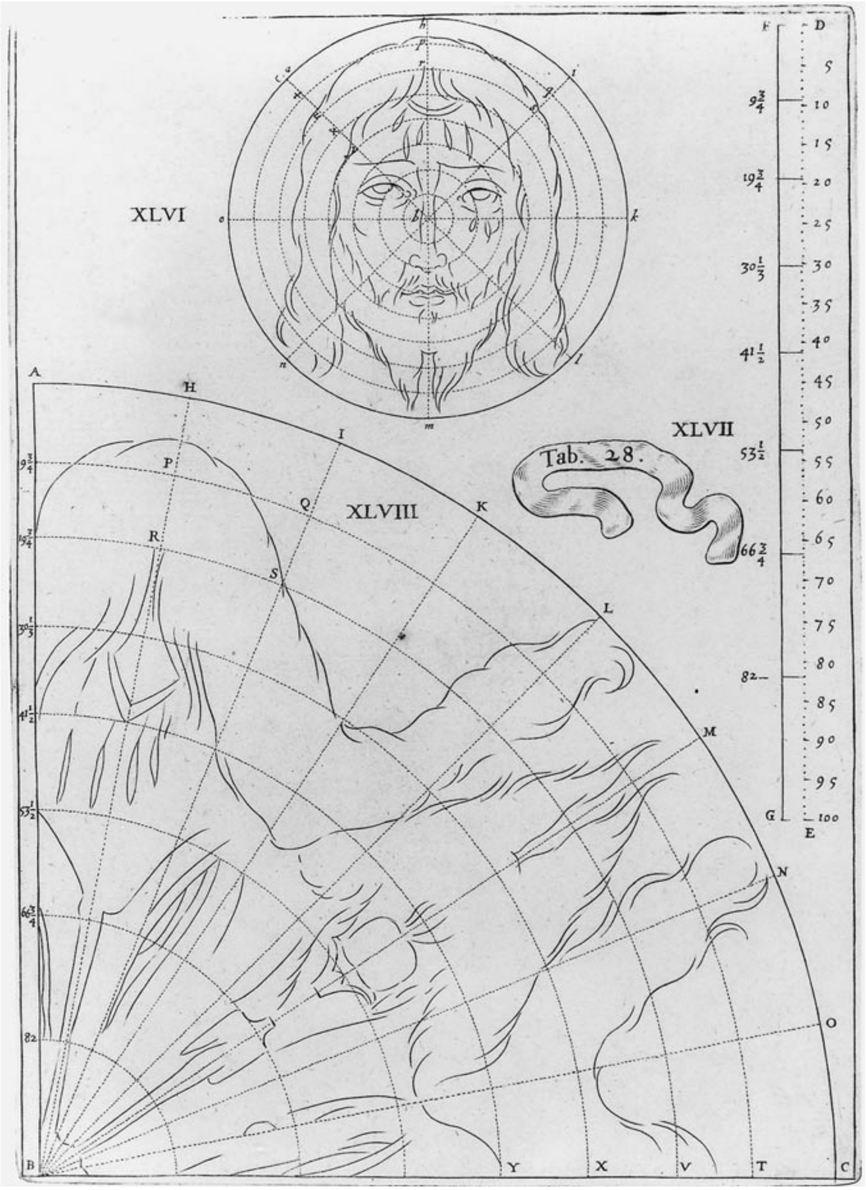

Figure 19.9 J.F. Nicéron, cone, from *La Perspective curieuse* (1638).

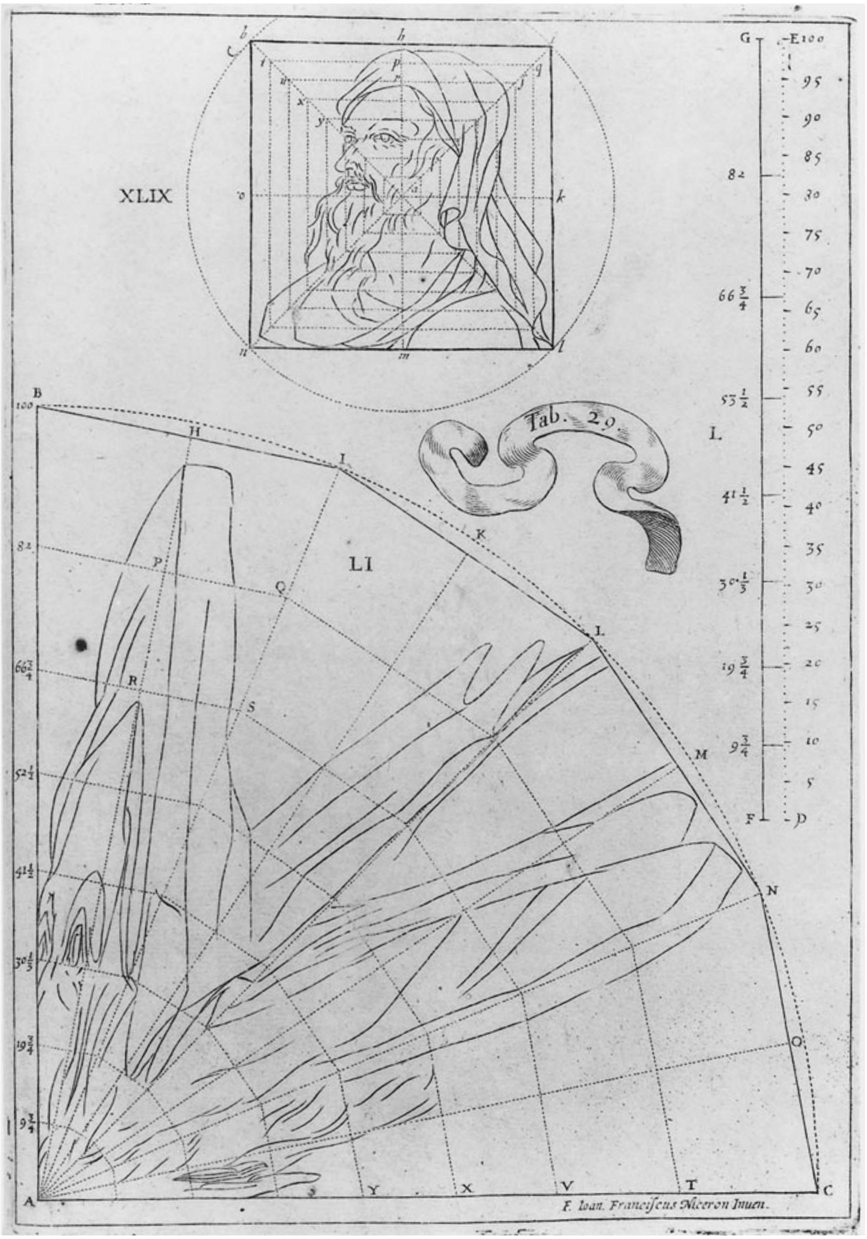

Figure 19.10 J.F. Nicéron, pyramid, from *La Perspective curieuse* (1638).

elongated anamorphosis, in some sense the simplest anamorphosis, involves stretching or skewing a rectilinear co-ordinate system; the others involve projections of more complicated grid systems (Figure 19.11). These anamorphoses show that an image can be distorted in certain ways, even to the point of being unrecognizable in conic anamorphoses, and yet the information can be 'reconstructed' by the appropriate mathematics.

Each kind of anamorphosis, however, gives us a different insight. In the elongated anamorphosis the distortion and the correction are not viewed simultaneously. The viewer has to shift position to understand the picture. For these, space alone is not adequate; motion must be added. In catoptric anamorphosis, on the other hand, both the distortion and the correction can be viewed simultaneously, but needs a special device, like a cylinder, cone, or pyramid. In these anamorphoses, not only can the image be distorted in particular ways, but different images, carrying the same information, can exist together.

A third kind of artistic 'play' involves two perspective points. In this kind of anamorphosis, two images, each with its own perspective point and perspective system, are included in the same picture. One of the most famous examples of this kind of picture is *The Ambassadors* by Holbein. This picture is in the Vanitas tradition. The ambassadors Jean de Denteville and Georges de Selve are portrayed in front of a table with items symbolising the human (a book, a globe, a musical instrument, and various mathematical devices). In the lower part of the picture is what at first appears to be a smear, but is actually from a far perspective point, a skull. As Kemp writes,

> What is the purpose of the semi-concealed skull? It almost certainly relates to the other partly-concealed symbol, the sculpted crucifix half-hidden by the curtain in the upper right corner. If the skull serves to remind us of the ultimate triumph of death over all human pursuits – even those as intellectually beguiling as astronomy, horology, cartography and music – the silver crucifix represents our only legitimate chance of salvation in the next life.[36]

A monumental two-point perspective fresco was painted by Emmanuel Maignan at the cloister of S. Trinità dei Monti, Rome, in 1642. J.-F. Niceron executed similar frescoes in the Minim monasteries in Rome in 1642 and in Paris in 1644. Viewed 'straight on' the fresco appears as a landscape with sailboats on the lake. Viewed as one walks down the cloister hallway, however, St. Francis of Paola appears. St. Francis of Paola, the patron saint of the Minim monks, was originally famous as 'a thaumaturge, a man who, with a wave of his hand and a word of prayer, could prevent rocks from falling on innocent victims below', heal the sick, cast out devils and raise the dead.[37] By the time of Maignan, however, the

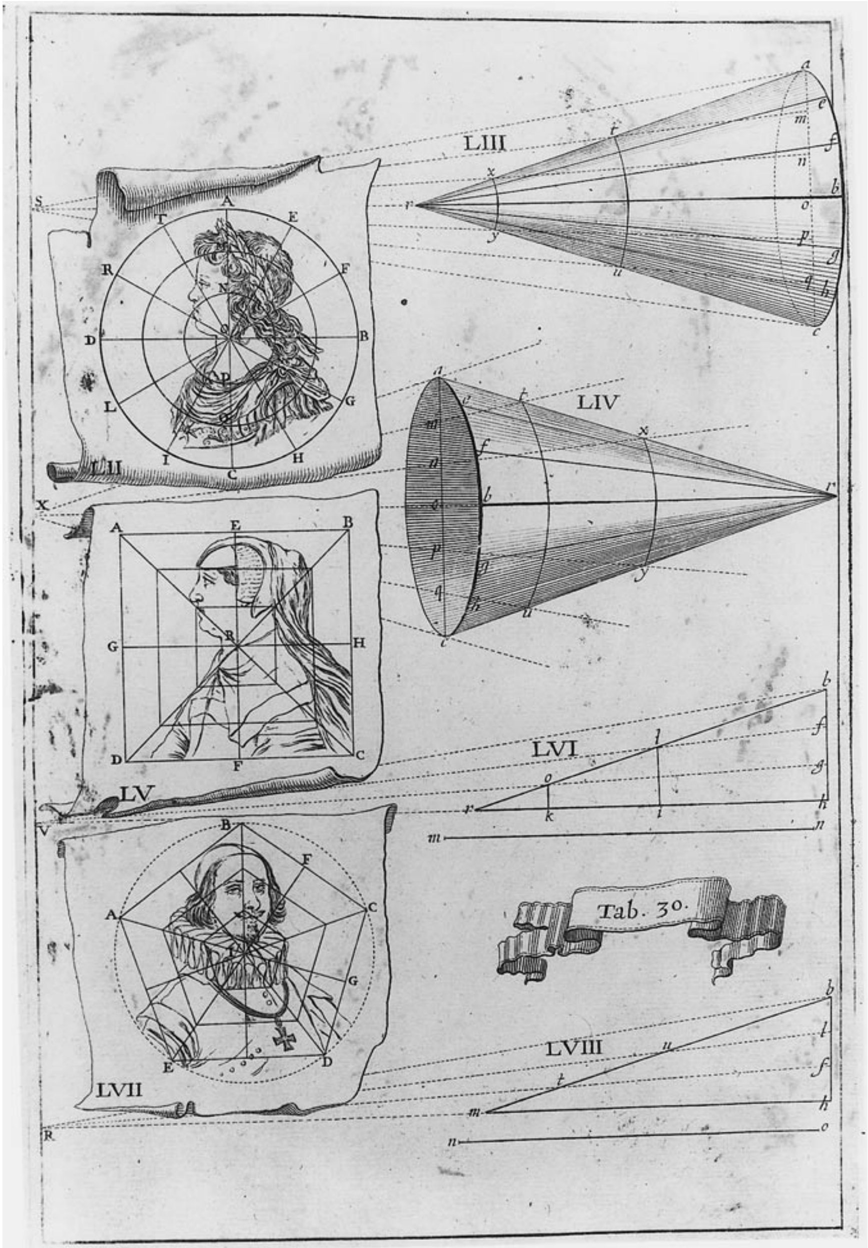

Figure 19.11 J.F. Nicéron, multiple grids, from *La Perspective curieuse* (1638).

Minims believed that one could behold spiritual in the natural, God in physics. The mural symbolizes how the spiritual work of St. Francis can be in or behind the natural world.[38] Figure 19.12 shows the elaborate framework, a grid system writ large, and the mathematics, that were employed to create these kind of frescoes.

Holbein's painting and Maignan-Niceron's fresco contrast in terms of perspectival 'spread'.[39] They each have two perspective points, but in Holbein's painting each perspective is localised, i.e. it occurs in a specific part of the painting. In Maignan-Niceron's fresco, however, the effects of each perspective point is distributed over the whole picture. The entire fresco can be viewed as a natural scene or it can be viewed as a tribute to St. Francis of Paola.

A final set of figures (Figures 19.13 and 19.14) illustrate another, fourth, kind of artistic 'play' in the seventeenth century. Both pictures are from Niceron's *La Perspective curieuse*. In Figure 19.13 there is a viewing device at a set distance from a wall. The device, the size and shape of a kaleidoscope, has a faceted lens. On the wall are several portraits of men. When one looks through the glass at the wall, the image that appears is that of Louis XIII – who is actually none of the people on the wall! It turns out that the pyramidal anamorphoses, such as the one illustrated by De Brueil, also create, from four faces, a new face, one that is constructed from parts of the four other faces.[40]

In the development of this perspectival 'play', we can see that once the

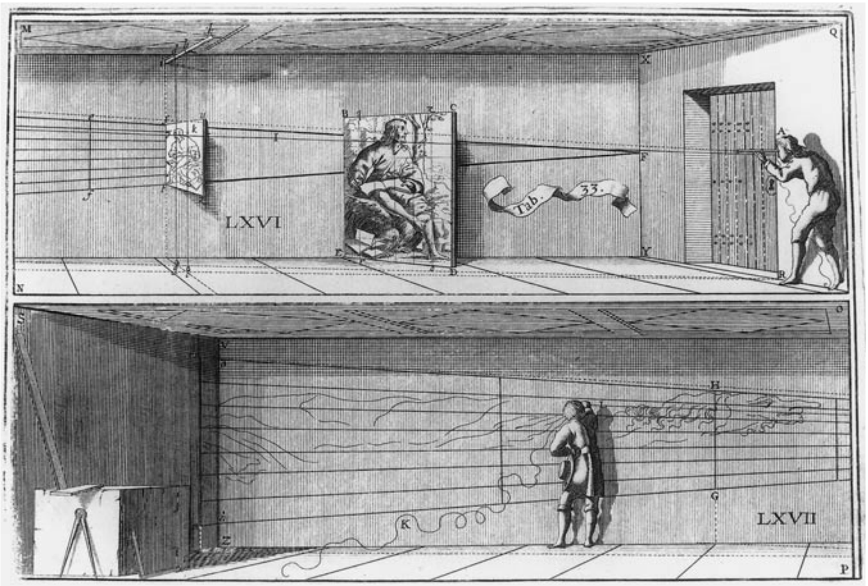

Figure 19.12 J.F. Nicéron, Framework – St. Jean l'Evangeliste, from *La Perspective curieuse* (1638).

Figure 19.13 J.F. Nicéron, from *La Perspective curieuse* (1638).

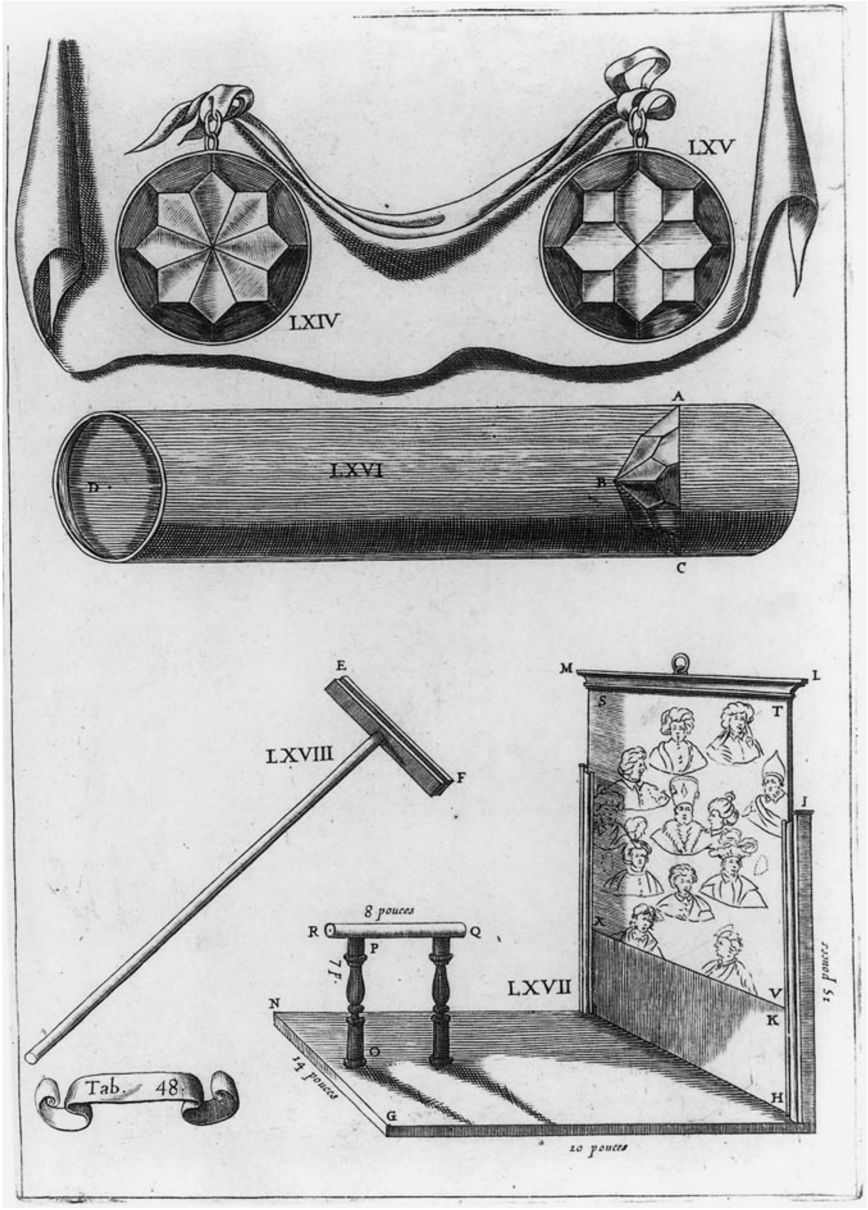

Figure 19.14 J.F. Nicéron, from *La Perspective curieuse* (1638).

image was free from resembling the object exactly, the question arose in what ways could it be different and how much could it vary? The freedom of the image from exact resemblance and mathematics combined to create anamorphic effects.

Encoding and decoding

We have already seen that for sense experience and for imagination the image is independent, at least in some respects, from the object. In the Fifth Discours of the *Dioptrique* which is entitled 'Of the images that form on the back of the eye', Descartes describes a room converted into a *camera obscura*, and then he shifts to explaining an experiment one can try with the eye of a dead man or dead ox. In this experiment the eye is set up as its own *camera obscura*. The back of the eye is carefully scraped away so that there is a small hole. This is done without spilling any fluid from the eye. Then a thin white film – Descartes suggests paper or an eggshell – is placed over the hole. The eye is placed in a specially constructed hole in a window shutter so that it faces objects outside which are illuminated by the sunlight. The rest of the room inside is dark. 'Having done this', Descartes proclaims:

> if you look at that white body, you will see there, not perhaps without wonder and pleasure, a picture which will represent in natural perspective all the objects outside – at any rate you will if you ensure that the eye keeps its natural shape, according to the distance of the objects (for if you squeeze it just a little more or less than you ought, the picture becomes less distinct).[41]

The metaphor of natural perspective for vision has both positive and negative aspects. On the positive side, it is wonderful that the images of objects appear so recognizable on the film (alternatively, on the back of the eye); on the negative side, however, the 'picture' is not perfect. In the eye of the ox, for example, the images will be fuzzy at the edges, reversed, and 'diminished and shortened – some more, some less – owing to the various distances and positions of the things they represent, much as in the same manner as in a picture done in perspective'.[42] The images in the eye of a person will be better, because the human eye is superior in certain ways, but even they will not be perfect.[43]

What is formed in the imagination, however, varies again. Here, Descartes' earlier theory of perception in the *Regulae* and his later one in the *Dioptrique* seem to differ about when images are transformed into motion. In Rule 12, Descartes develops his early theory about the role of the imagination in vision by a mixture of two different metaphors: one of a piece of wax and a seal, which implies an image is transferred, and the other by the movement of a pen, which implies that motion is turned into a different motion. The 'common sense', Descartes tells us, 'functions like a seal, fashioning in the phantasy or imagination, as if in wax, the same figures or ideas which come, pure and without body, from the external senses'.[44] But immediately after this Descartes writes:

> Fourthly, the motive power (i.e. the nerves themselves) has its origin in the brain, where the corporeal imagination is located; and the latter moves the nerves in different ways, just as the 'common' sense is moved by the external senses or the whole pen is moved by its lower end. This example also shows how the corporeal imagination can be the cause of many different movements in the nerves, even though it does not have images of these movements imprinted on it, but certain other images which enable these movements to follow. Again, the pen as a whole does not move in exactly the same way as its lower end; on the contrary, the upper part of the pen seems to have a quite different and opposite movement.[45]

In the change from the common sense to the imagination (the wax analogy), many of the features (like the size and the shape) of the seal carry over to the wax impression, although if we think about it, the impression is actually inverted (and, if it is poorly impressed on the wax, could be also indistinct). But the product of the imagination is very different from the impression provided by the common sense. The analogy here is with the motions of a pen. The motions of the upper end of the pen are not exactly like the motions of the lower end, but more than this, they are not even similar in direction or size. The motion of the large end of the pen represents the motion of the small end of the pen because certain relationships have been preserved, not exactly, but proportionately. The imagination is 'flexible': it can take the image from sense-perception and transform it into 'other images'. We do not have to worry whether the images exactly represent the object; nor do we have worry that the image, whatever it is, stays as the same object. As long as the transformation is systematically proportional, the information of the image is carried on.

In the *Dioptrique*, the information from the image is transformed into motion at the back of the eye.[46] It is then the motion which transmits the information about what was seen. Descartes writes:

> Now, when this picture thus passes to the inside of our head, it still bears some resemblance to the objects from which it proceeds. As I have amply shown already, however, we must not think that it is by means of this resemblance that the picture causes our sensory perception of the objects – as if there were yet other eyes within our brain with which we could perceive it. Instead we must hold that it is the movements composing this picture which, acting directly upon our

> soul in so far as it is united to our body, are ordained by nature to make it have such sensations.[47]

Furthermore, the movements which carry the information may be composed by various proportionalities. With respect to the quantity of light we attribute to objects, to take just one of Descartes' examples, the force with which a optic nerve fibre is moved is

> not always equal to the light which is in the objects, but varies in proportion to their distance and the size of the pupil, and also in proportion to the area at the back of the eye which may be occupied by the rays coming from each point.[48]

One way to explain this is by means of an analogy with encoding and decoding. Information about objects becomes encoded in images on the retina, and the information in the images becomes encoded into movements in the optic nerve. The information in these movements can, in turn, be encoded in other movements. What is retained in all these various codings is the information, specifically proportional relationships. The information about one thing relative to another can be retrieved or reconstructed.

Anamorphic art in its various forms gives us examples of how information can be variously encoded and retrieved. Elongated metamorphoses show that a skewed rectilinear grid can be 'normalised'. The catoptric anamorphoses of the different types (cylindrical, conical, pyrimidal) demonstrate that an image can be distorted in certain ways, even to the point of being unrecognizable, and yet the information can be reconstructed by transforming the novel picture grid into a rectilinear co-ordinate system. The special 'telescope' of Niceron gives us a model for how we could trace information back, through the angles of the lens facets, to its source(s). Did the information come from what it seemed to, or from another cause or set of causes?

Furthermore, anamorphic art shows us different combinations of encoding/decoding. In an elongated anamorphosis and two-point anamorphosis there is both a distortion of the representation and a 'correction' for it, but the distortion and the correction are not viewed from the same place or at the same time. The encoding and the decoding are separate. In catoptric anamorphosis, however, both the distortion and the correction can be viewed simultaneously. Not only can the image be distorted in particular ways, but different images, carrying the same information, can exist together and encoded information can be simultaneously decoded.

These anamorphic pictures may give us a partial analogy for the flexibility of the imagination. For Descartes, the information from the senses can be encoded in more than one way (e.g. as an image, as motion).

Moreover, it can be encoded in more than one way simultaneously. These encodings preserve relationships and proportionalities. What I am suggesting as a way to understand Descartes' constructive sense of the imagination is that it acts not just as the early perspectivists' rectilinear grid, but as a number of geometrical grids – rectilinear, curvilinear, etc. On this analogy, the positive function of the imagination is as a master mathematical decoder for various transformations of images.[49] In some cases, the decoding may be fairly straightforward, as in assessing distance of objects within optimal range of vision ('a simple act of the imagination . . . as if by natural geometry');[50] in other cases the decoding may take considerably more analysis and calculation, as in assessing the distance of objects greater than 100 or 200 feet away or assessing the distance of images in a mirror, or in concave or convex surfaces.[51]

The 'play' of anamorphic art seems to be connected to an even more general interest in the sixteenth and seventeenth century about encoding and decoding information.[52] During this time, for example, more and more complex codes were developed for transmitting secret (especially political and military) information. There was also interest in how information could be compressed – in shorthand or secret writing – and still be recoverable. Some of the anamorphic images, too, were used to convey secret information – some were lewd[53] and others were political.[54] The connection between the positive role of the imagination and code breaking in general is fascinating. Since decoding is often mathematical – based on the relative frequency of letters in a language – it is certainly possible that Descartes was intrigued by cryptography in general and that a further understanding of this would enrich the analogy that I have so far offered. In this paper, however, I have been interested in how images, rather than words, can be transformed and reconstructed, and thus have emphasized anamorphic art. The details of encoding and decoding in general and Descartes' relationship to it are at this point left to further research.

Descartes' concern with images and their transformations and reconstructions is closely tied to another part of his seventeenth-century context: the development of both telescopes and microscopes.[55] Descartes, in fact, announces this pragmatic concern at the opening of the *Dioptrique*.

> The conduct of our life depends entirely on our senses, and since sight is the noblest and most comprehensive of the senses, inventions which serve to increase its power are undoubtedly among the most useful there can be. And it is difficult to find any such inventions which do more to increase the power of sight than those wonderful telescopes which, though in use for only a short time, have already revealed a greater number of new stars and other new objects above the earth than we had seen there before. . . . But inventions of any complexity do not reach their highest degree of perfection right away,

and this one is still sufficiently problematical to give me cause to write about it.[56]

There were many problems. When Galileo first turned the telescope on the sun and saw spots, for example, he had to figure out what they were. In the prevailing philosophy, the sun was perfect and could not be blemished, so the traditionalists tried to explain the spots as additional objects orbiting between the earth and the sun. Galileo carefully recorded the clustering and moving of the spots. Following a particular group of spots, he noticed that they were more spread out across the centre of the sun than they were at the edge. The ratio of difference would be consistent with spots moving across the surface of a globe (and not consistent with stars or planets moving in an orbit some distance from the sun). Galileo's argument, as Kemp points out, relies on the principles of anamorphic foreshortening on spherical surfaces.[57]

And this was just the beginning. There were also problems created by the instruments themselves. The lenses were not uniform, but had defects or impurities in them that could cause distortions and illusions. In terms of microscopy, for example, some of the earliest Dutch microscopes used a single bead of glass as the lens. Such spherical lenses caused aberrations.[58] Descartes recommends lenses of a hyperbolic shape and his argument shows an awareness of spherical distortion. He writes: 'and aside from the fact that it is hard to find much difference between the hyperbolical and the spherical shape, this difference is much more apparent towards the extremities of the lens than towards its centre.'[59]

Thus, not only was vision itself imperfect in certain ways, but optical instruments added their own complications. The images might be doubly or triply skewed, distorted, inverted, reversed, smaller or larger, fuzzy, or even just illusions. It was important to have a way to figure out what (if anything) was real, given what one saw. Understanding how images could be transformed and yet mathematically reconstructed became part of the solution. The imagination, by means of mathematics, would help[60] us decode our experiences.

Possible reinterpretations

As we have already seen, Descartes uses the case of engravings in Part IV of *Dioptrique* to show that an image need only resemble its object in a few respects. In Meditation I, however, Descartes questions, by means of illusions, the resemblance assumption of perception (that objects resemble the way that they appear) and he questions, by means of the dream argument, the causal assumption of perception (that there are objects outside of us that cause at least some of the sensations that we have). In Meditation VI, Descartes finally reinstates the causal assumption, but he never reinstates the resemblance assumption. (There is, for example, no pain in the flame of a candle.) One question that arises from these apparently contrasting texts is whether Descartes only weakened the resemblance assumption or completely abandoned it?

Furthermore, if Descartes has abandoned the resemblance assumption entirely, what are the implications of that? Different commentators draw different conclusions. Theo C. Meyering, for example, lauds Descartes for understanding that the scientific developments of optics forced the abandonment of the resemblance assumption on both the biological and the psychological levels.[61] According to Meyering, Descartes' shift from a copy theory to a causal theory allowed for the 'possibility . . . of an informational theory of perception'.[62] Meyering goes on to argue, however, that Descartes' insight only allowed for the possibility of such a theory; Descartes did not manage to develop such a theory himself.

> According to Descartes the mind is pure and ever-active thought of consciousness. The body, by contrast, is no more than extended matter-in-motion. There is nothing 'in-between'. The interaction between the two substances is thus immediate, there being no vehicle for interaction that could bridge the gap as it were.[63]

Thus, Meyering concludes, 'Descartes' theory was not so much a theory of information processing in the proper sense but at best a psycho-physiological correlation theory without a detailed insight into the nature of the information-handling processes.'[64] According to Meyering we are, in short, left with a mystery.

Brian Baigrie, on the other hand, thinks that because there is no resemblance between the image and the object, the relationship between them is basically symbolic. He writes: 'The view that squares with Descartes' treatment of sensation in the *Dioptrique*, however, is that the mind only has a symbolic knowledge of objects in virtue of the motions they set up in the nervous system.'[65] There is some support for Baigrie's remark. There is, for example, the passage in which Descartes, taking the extreme position, perhaps to challenge our presumptions, writes that 'we should, however, recall, that our mind can be stimulated by many things other than images – by signs and words, for example, which in no way resemble the things that they signify'.[66]

The rejection of the resemblance assumption certainly complicates the story that needs to be told, but I do not believe that we are left with either a complete mystery or mere symbolism. First of all, both Meyering and Baigrie acknowledge a causal correlation between the object and the image. Whether Descartes merely weakened or entirely rejected the resemblance assumption, he did not abandon the causal assumption, so causal relationships are an important part of Descartes' natural philosophy and must be preserved in interpreting his views.

Meyering's and Baigrie's accounts, however, are connected in another way. I suggest that Meyering is left with a mystery because he has fallen victim to analytic philosophy's disregard for the imagination, and that Baigrie is left with a merely symbolic connection between the image and the object because he fails to see the possible richness and flexibility of the imagination. The interpretation of imagination that has been developed in this paper provides alternatives.

Baigrie realizes that images are important to Descartes. But once the image does not resemble the object there is a curious slippage from 'the image does not resemble', to 'the image does not represent', to 'the image does not correspond'.[67] This ultimately leaves Baigrie with no other explanation of the relationship between the image and the object than that one is a symbol for the other. The problem is that symbols can be arbitrary and can have notoriously little connection to what they symbolise.

In the analogy with perspectival art, the imagination is thought of as a set of grids – rectilinear, curvilinear, etc. – each of which provides a network of relationships. Transformations between the grids do not preserve the appearance of the image, but they do preserve information about the proportional relationships. In light of the analogy it is possible to abandon resemblance, but to maintain a correspondence between the image and the object. Furthermore, each of the anamorphic grids can be rendered into its equivalent rectilinear grid, and a rectilinear grid can be transformed into any of the others. This gives us a way to understand how experience may come to us skewed or variously distorted, but the imagination, by the use of the appropriate grid and transformation, can serve as a Master Decoder of the mathematical relationships in the experience.

Furthermore, in answer to Meyering's frustration, the imagination may provide the 'vehicle for interaction that could bridge the gap' between the mind and the body. On this interpretation, imagination, in its constructive mathematical use, provides a way to process sensory experience for its information, at least about proportionalities. Thus, Descartes' view of the imagination may provide a beginning insight into what Meyering refers to as 'information-handling processes'.

Finally, the analogy explains why Descartes seems sometimes to just weaken the resemblance assumption and at other times abandon it entirely. Some pictures, those of natural perspective, have some resemblance to the objects they represent; others, like the ones that are conical, may have no resemblance to what they represent, at least until they are transformed. What is crucial is not the amount of resemblance, but the encoding of information.

Text and context

So far, the purpose of this chapter has been to elucidate some of the developments in perspectival art in the fifteenth to seventeenth centuries and some of their connections with concurrent optical inquiries. It has been suggested that understanding what is involved in the increased mastery in perspectival art and the experiments of anamorphic art at this time may provide us with an analogy for understanding some of Descartes' comments about the imagination in its constructive role of mathematising experience. Is there any more to this than an interpretive analogy? Is there a connection between Descartes' experiments in optics and the work of the artists of his time? We can begin to build a case using both textual evidence and contextual evidence.

In terms of textual evidence, there are, first of all, numerous places, some of which have already quoted, where Descartes makes an analogy with painting (or sometimes the painter) to clarify his point. Perspective in art is an active, ongoing analogy for Descartes, not just a passing comment.

Textual evidence of a different sort is revealed in some of Descartes' examples. To take one instance, Descartes begins his famous methodic doubt by questioning sense experience.

> But from time to time I have found that the senses deceive, and it is prudent never to trust completely those who have deceived us even once. Yet although the senses occasionally deceive us with respect to objects which are very small or in the distance, there are many other beliefs about which doubt is impossible, even though they are derived from the senses – for example, that I am here, sitting by the fire, wearing a winter dressing-gown, holding this piece of paper in my hands, and so on.[68]

This of course leads us to the dream argument. At this point Descartes only gives two brief examples of sense-deception – being deceived with respect to objects which are very small or in the distance. In Meditation VI, however, Descartes fills in his general examples from Meditation I with these more concrete examples:

> Sometimes towers which had looked round from a distance appeared square from close up; and enormous statues standing on their pediments did not seem large when observed from the ground.[69]

These are both examples from perspective and the second one is actually from anamorphic art – how to make statues appear realistic when the point of view is from below looking up.

A third kind of evidence may be inferred from the effectiveness of perspectival art to explain troublesome passages. One of these is the argument which occurs near the end of Meditation I:

> Nonetheless, it must surely be admitted that the visions which come in sleep are like paintings, which must have been fashioned in the like-

> ness of things that are real, and hence that at least these general kinds of things – eyes, head, hands, and the body as a whole – are things which are not imaginary but are real and exist. For even when painters try to create sirens and satyrs with the most extraordinary bodies, they cannot give them natures which are new in all respects; they simply jumble up the limbs of different animals. Or if perhaps they manage to think up something so new that nothing remotely similar has ever been seen before – something which is therefore completely fictitious and unreal – at least the colours used in the composition must be real. By similar reasoning, although these general kinds of things – eyes, head, hands and so on – could be imaginary, it must at least be admitted that certain other even simpler and more universal things are real. These are as it were the real colours from which we form all the images of things, whether true or false, that occur in our thought. This class appears to include corporeal nature in general, and its extension; the shape of extended things, the quantity, or size and number of these things; the place in which they may exist, the time through which they may endure and so.[70]

In this passage an analogy with paintings connects the dream argument to mathematics. The analogy, simply put, is that pigments are to paintings the way the mathematics of corporeal objects is to dream-images. On the surface, the analogy seems to rely on a similarity of analysis. Paintings can be analyzed into at least bits and dabs of paint in the same way that dream-images can be analyzed into at least more simple, quantifiable, relationships. On deeper thought, however, the analogy seems curious for two reasons. First, we usually do not do measurements and calculations on our dream images. Second, the connection between dream-images and paintings seems puzzling. An awareness that images in general, including dream-images, can be placed in relationship to one another by means of perspectival grids deepens the analogy for images. In dreams, for example, I can appear to be sitting near the fire. At the same time, the hidden, but perhaps common, basis of perspectival grids could explain the connection that Descartes apparently makes so easily between dream-images and painting-images. Mathematics is behind the objects and images of corporeal nature in general, and behind dream-images of them, and it is really behind paintings, too.

There is also mounting evidence that Descartes not only lived in this rich context of perspectival art, but was personally surrounded by it and even engaged in it in certain ways. One connection to the world of perspectival art on the French side is through Mersenne, Descartes' longtime friend and correspondent. Mersenne is a Minim monk, and where does he live? He happens to live in the Minim monastery in Paris where Niceron executed his anamorphic murals. Furthermore, Mersenne sent a copy of Niceron's *La Perspective curieuse* to Descartes, and Descartes thanks

Mersenne in a letter dated 30 April 1639. In return, Descartes sends Niceron a copy of his *Discours*.

While Descartes is corresponding with Mersenne and others in France, moreover, he is living in Holland. The Dutch interconnections of art and optics are intricate, intriguing, and have been largely ignored. To build this part of the case we must reconstruct the rich context from bits and pieces. For example, there was Cornelis Drebbel (1572–1633) who was approximately a generation older than Descartes. Apprenticed originally to the painter/engraver Goltzius (himself an alchemist of sorts), Drebbel developed into what today might call a scientist/tinkerer.[71] At the time, however, many people were unsure what to make of some of his work, and feared he was, instead, an alchemist/magician. According to Tierie, Drebbel was associated with various mechanisms and inventions, including a pump clock, the fountain at Middleburg, a patent for a chimney, 'a perpetual motion' machine, automatic musical instruments, the telescope, the microscope, a submarine, and perhaps the purification of oxygen.[72] As perhaps a prototype of an early seventeenth-century Dutch scientist, he is worth further investigation.

One of the reasons that Drebbel is significant to my argument is that he was part of a mathematical/optical nexus in Holland. Drebbel himself was an accomplished glass-blower and lens grinder and made both telescopes and microscopes. Furthermore, he grew up in Alkmaar and was friends with the Metius brothers. Jacob Metius, the younger brother, was himself an excellent lens maker and, in fact, Descartes gives him credit at the beginning of the *Dioptrique* as the discoverer of the telescope.[73] Adriaen Metius, the elder brother, was a famous astronomer and mathematician. Tierie writes of him that he

> first studied at the Universities of Franeker and Leyden and later devoted himself, together with his friend, the well-known cartographer, Willem Jansz. Blaeu, more especially to the study of astronomy, under the famous Tycho Brahe. In 1597 he was appointed professor at Franeker where he excelled not only in astronomy, but also in arithmetic and surveying; he made a map of Friesland by trigonometry; furthermore he was a doctor of medicine and a passionate alchemist.[74]

Tierie claims that Descartes was Metius' student while he was at the University of Franeker.[75]

Drebbel is also important to this paper because he, along with Constantyn Huygens, created some of the links between science and art in the Dutch Republic. Drebbel himself was trained as a painter and engraver. Furthermore, he enjoyed fascinating people with a camera obscura. In fact in 1622, Constantyn Huygens (the elder) as a young man visited Drebbel (now in England), and bought one of Drebbel's camera obscuras which he brought back to Holland. Huygens was eager to, and apparently did, introduce the camera obscura to his Dutch friends, many of whom were artists.[76]

Intriguing also is another almost forgotten person, Frans Van Schooten. Frans Van Schooten was a mathematician, and Descartes helped him get his position at the University of Leiden upon the death of his father, Van Schooten the elder. Frans Van Schooten, the younger, and Descartes were collaborators. Van Schooten translated the *Discours* and later the *Principia*. He also drew the figures in the *Discours* and made one of the few portraits of Descartes we have. So here Descartes is connected to a minor artist in Holland. But it turns out that Franz Van Schooten is the brother of Jorvis Van Schooten, the best portrait painter in Leiden and a teacher of Rembrandt (among others).[77]

What is left of this network of Dutch friends and their exchange of ideas must be gleaned from correspondence and other textual resources. We do have some direct textual evidence for Descartes interest in perspectival art. In 1618 Descartes began serving in the army of Prince Maurice of Nassau. How did he serve in the army? Borel says he was a soldier, but others have him as an army engineer. Army engineers at that time were often artists as well as mathematicians – drawing maps, fortifications, devices, etc. On 24 January 1619 Descartes wrote to Beeckman: 'On the contrary, I have never been more usefully employed – but on matters which your intellect, occupied with more elevated subjects, would no doubt despise, looking down on them from the lofty heights of science, namely painting, military architecture and above all, Flemish.'[78]

Furthermore, it is clear that Descartes and his friends were among the people doing optical research. In his own early description he connects this work with perspective:

> In a garden we can produce shadows to represent certain shapes, such as trees; or we can trim a hedge so that from a certain perspective it represents a given shape. Again, in a room we can arrange for the rays of the sun to pass through various openings so as to represent different numbers or figures; or we can make it seem as if there are tongues of flame, or chariots of fire, or other shapes in the air. This is all done with by mirrors which focus the sun's rays at various points.[79]

And finally, Borel, Descartes' very first biographer, also makes the connection between optics and anamorphic art when he records Descartes' fascination with 'Prospectives':

> He was so eminent in the Mathematicks, that he did things beyond apprehension, especially about prospectives; and to the end that he might prove his experiments, he prepared Prospectives of a large size, either of ice or of artificial black polisht marble made hollow according to his desire, and the various forms he phancyed by the assistance

> of Brefsiaus, a most ingenious man; and when he had accomplisht his design, he brake them in pieces and made new ones of the same matter. And before the same Brefsiaus, by a hidden secret in Opticks he would show him a company of souldiers marching in his chamber, which he did much admire; but this proceeded from the small figure of souldiers which he conceal'd and brought forth multiplied without doors.[80]

The last sentence here describes a camera obscura; the first paragraph describes the different kinds of surfaces with which Descartes experimented to learn about images and their projections.

Conclusion: a Cartesian anamorphosis

One thing I hope that I have accomplished is an anamorphosis of Descartes himself. Viewed directly, as a philosopher, as the writer of the *Meditationes*, we focus on God, soul and the role of the understanding in gaining knowledge of these non-corporeal things. Viewed from another perspective, as a philosopher-mathematician-scientist, as the author of the *Regulae*, *Le Monde*, and the *Dioptrique*, we see the natural world where the understanding can be aided by both imagination and sense-experience. In a sense the anamorphosis is conceptually the reverse of the Niceron-Maignan's fresco at S. Trinità dei Monti. In the mural, the direct view gives us a landscape and St. Francis of Paola only emerges indirectly. In viewing the Cartesian corpus, the direct view is supposed to show us God and soul; it is the indirect view which gives us the landscape of the natural world though natural philosophy.

I think that Descartes himself would be unhappy that we have focused so directly on his philosophical work and have failed to take the 'longer' perspective. In his letter of 28 June 1643 to Elizabeth, he writes:

> Finally, although I believe it is quite necessary to have understood, once in one's life, the principles of metaphysics, because it is through them that we receive knowledge of God and of our soul, I believe too that it would be very harmful to devote one's understanding to meditations about these principles, because we cannot attend as well to the functions of the imagination and the sense. It is better to be content with retaining in memory and in belief the conclusions that one has at one time drawn, and to employ the rest of the time that one has for study for thoughts in which the understanding acts with the imagination and the senses.[81]

Notes

1 AT x. 399 (my emphasis).
2 AT x. 411.
3 AT x. 416–17.
4 Letter to Elizabeth, 28 June 1643; AT iii. 691–2.
5 AT x. 399.
6 Ibid.
7 AT x. 430.
8 AT x. 438.
9 AT x. 440.
10 AT vi. 95.
11 AT vi. 88.
12 AT vi. 105.
13 AT vi. 137–40.
14 AT vi. 137–8.
15 Nancy L. Maull complains that 'philosophers and historians of science have ignored Descartes' solution to the geometrization problem . . . [because of] an orthodoxy of misplaced emphasis on Descartes' more "philosophical" texts': 'Cartesian Optics and the Geometrization of Nature', in S. Gaukroger, ed., *Descartes: Philosophy, Mathematics and Physics* (Brighton, 1980), 35. In the paper she places Descartes in context with Berkeley and Kant (philosophers) and Galileo and Kepler (scientists). She does not, however, realise the connection between optical problems and art.
16 I thank Dr. Samuel Edgerton of Williams College for this insight generated by his informative lecture series at the NEH Columbus Quincentenary Institute at UCLA in 1989. Recent scholarly work showing the interdisciplinary aspects of art, optics and mathematics include Martin Kemp, *The Science of Art* (New Haven, 1990) and J.V. Field, *The Invention of Infinity* (Oxford, 1997).
17 In his Notebooks, Leonardo Da Vinci divides the study of perspective into three subfields: '. . . the first includes the diminution in size of opaque objects; the second treats of the diminution and loss of outline in such opaque objects; the third, of the diminution and loss of colour at long distances'. (*The Notebooks of Leonardo Da Vinci vol. 1*, ed. by Richt (New York, 1970), 15.
18 Leon Battista Alberti, *On Painting*, trans. John R. Spencer (New Haven, 1972), 90.
19 Alberti writes: 'It is now manifest that every cross-section of the visual pyramid which is equidistant to the plane of the thing seen [for us read parallel to the plane of the thing seen] will be proportional to that observed plane'. (ibid, 54).
20 While Alberti recognized the importance of changes in shadows and light, especially to indicate the different planes of a curved surface, and he talked of visual pyramids of lights and colours, he did not work out the geometrical details. He recommended, instead, that one learn these changes by observing nature (Alberti, 83). DaVinci, writing in 1490 and after, attempted to explain the geometry of shadows and the ratios between shadows and light, but in his work on colour perspective he suggests the following: 'In order to put into practice this perspective of the variation and loss or dimunition of the essential character of colours, observe at every hundred braccia some objects standing in the landscape, such as trees, houses, men and particular places. Then in front of the first tree have a very steady plate of glass and keep your eye very steady, and then on this plate, draw a tree, tracing it over the form of that tree. Then move it on one side so far as that the real tree is close by the side of the tree you have drawn; then colour your drawing in such a way as that in the

colour and form the two may be alike, and that both, if you close one eye, seem to be painted on the glass and at the same distance. Then, by the same method, represent a second tree, and a third, with a distance of a hundred braccia between each. And these will serve as a standard and guide whenever you work on your own pictures, wherever they may apply, and will enable you to give due distance in those works. But I have found that as a rule the second is 4/5 of the first when it is 20 braccia beyond it.' (Da Vinci, op. cit. i. 294). For aerial perspective, that objects in the distance are bluer. Da Vinci writes that the blueness increases in direct proportion to the distance (ibid, i. 295).

21 Alberti, op. cit., 113–4, n. 48.

22 Kemp, op. cit., 12ff.

23 See, for example, Da Vinci, i. 213, 214.

24 See, for example, Da Vinci, i. 83.

25 See, for instance, Rule 14, AT x. 442–3.

26 AT viiiA. 25.

27 AT viiiA. 26.

28 AT vi. 137–8.

29 C. Pendretti, *Leonardo Da Vinci on Painting: A Lost Book (Libro A)* (Berkeley, 1970), 70.

30 AT xi. 3.

31 AT vi. 113.

32 AT vi. 113–14.

33 Da Vinci, i. 109. The use of 'natural' here in contrast to artificial may, perhaps, begin to raise questions about what Descartes means by 'natural geometry' or 'natural perspective'. Usually, 'natural geometry' is taken to mean one that is automatic, given without reflection. This natural geometry is often assumed to be innate (see, for example, Maull, op.cit., 23). Another possibility is that 'natural' could refer to normalised rectilinear geometry and 'artificial' to skewed or even non-rectilinear geometry.

34 Jurgis Baltrusaitis, *Anamorphic Art* (New York, 1969), 18.

35 Fred Leeman, Joost Elffers and Michael Schuyt, *Anamorphoses* (New York, 1976).

36 Kemp, op. cit., 209.

37 P.J.S. Whitmore, *The Order of Minims in Seventeenth Century France* (The Hague, 1967), 60.

38 Ibid., 117 and 141.

39 I thank John Sutton for this distinction between localised and distributed spread. The terminology comes from cognitive science.

40 John Sutton has pointed out that at the end of the nineteenth century there was an interest in creating composite images photographically by an averaging technique. This is related perhaps to how the brain creates paradigms. The composite faces were often considered more beautiful than the individual faces. See Janet Metcalfe's 'Composite Memories' in W. Hockley and S. Lewandowsky, eds., *Relating Theory and Data* (Hillsdale, 1991). Niceron's 'telescope', which created a new face from other existing portraits, seems to have been more politically influenced. See Niceron, *La Perspective curieuse*, 189.

41 AT vi. 115–16. In this passage Descartes clearly reveals the connection of optics as a science (in terms of an experiment) with art (in terms of natural perspective) that was typical in the seventeenth century.

42 AT vi. 124.

43 AT vi. 124. One can compare Descartes' view with recent cognitive science literature about assessing distance. See, for example, William Epstein and Sheena Rogers, *Perception of Space and Motion* (New York, 1995) and Robert L. Solso, *Cognition and the Visual Arts* (Cambridge, MA, 1994).

44 AT x. 414.
45 AT x. 415.
46 AT vi. 129.
47 AT vi. 130.
48 AT vi.132.
49 Another difference between Descartes' early theory of perception in the Rules and his later one is that in the *Regulae*, the imagination contributes as an encoder of images to motions as well as a decoder. In the *Dioptrique*, however, the encoding does not appear to be done in the imagination. The imagination, instead, serves as the mathematical decoder of transformations that occur in the body/mind.
50 This gives another possible interpretation of 'natural' in the 'natural geometry': that the natural geometry is that of the rectilinear co-ordinate system; other geometrical systems (circular, etc.) are less natural.
51 AT vi. 143–5.
52 Writing at this time on cryptography and stenography are, for example, August, Duke of Braunschweig-Luneburg (1624); Kessler (1615), Kircher (1663), N.B. (Noah Bridges) (1659), della Porta (1563), Schott (1665), Trithemius (1608), Wilkins (1641). The definitive history of cryptography is David Kahn's *The Codebreakers: The Story of Secret Writing* (New York, 1967). Niceron wrote two books on anamorphic images: *La Perspective curieuse* and *Thaumaturgis Opticus*. He wrote also translated a treatise on deciphering codes by A.M. Cospi (Whitmore, op. cit., 161).
53 See, for example, Baltrusaitis, op. cit., 12.
54 See, for example, Baltrusaitis, op. cit., 28 and 105.
55 It seems to have been part of our bias that in the history of science that we have tended to pay more attention to the development of ideas in physics and astronomy – hence Galileo and the telescope – than to the development of ideas in biology – for instance, Leeuwenhoek and the microscope. Two recent books which begin to remedy this oversight are Catherine Wilson, *The Invisible World:* (Princeton, 1995) and Edward G. Ruestow, *The Microscope in the Dutch Republic* (Cambridge, 1996).
56 AT vi. 81–2.
57 Kemp, op. cit., 95. Kemp makes a wonderful connection between science and art at this point. In 1610–12 Galileo was in correspondence with Cignola, a artist/mathematician who was painting the Virgin of the Immaculate Conception in the dome at Sta. Maria Maggiori at that time. Kemp writes Galileo explains the sunspots this way: 'The spots near the edges are seen *in scorcio* (in foreshortening) while those near the centre are seen i*n faccia* (flat on).' Furthermore, Kemp points out, 'These are precisely the terms he uses when discussing anamorphic images in one of his two surviving letters to Cignoli.' (95).
58 For a more complete understanding of early Dutch microscopes see Ruestow, op. cit., 15ff and various works by Brian J. Ford including *Single Lens: The Story of the Simple Microscope* (London, 1985), *The Leeuwenhoek Legacy* (London, 1991).
59 AT vi. 211.
60 I put it this way, because in the next section I will argue that there was a limitation to the imagination's ability to decode.
61 Theo C. Meyering, *Historical Roots of Cognitive Science* (Boston 1989), 83.
62 Ibid., 84.
63 Ibid., 88.
64 Ibid., 89.
65 Brian S. Baigrie, 'Descartes' scientific illustrations and "l*e grand mechanique de la nature*" ', in Brian S. Baigrie, ed., *Picturing Knowledge* (Toronto, 1996), 115.
66 AT vi. 113.

67 Baigrie, op. cit., 122.
68 AT vii. 18.
69 AT vii. 76.
70 AT vii. 19–20.
71 L.E. Harris writes that Goltzius, while famous for painting and engraving, experimented with chemicals. He mentions a comment from Huygens that Goltzius 'had lost an eye from an explosion during the course of one of his experiments'. L.E. Harris, *The Two Netherlanders: Humphrey Bradley and Cornelis Drebbel* (Leiden, 1961), 127.
72 Garret Tierie, *Cornelis Drebbel* (Amsterdam, 1932).
73 AT vi. 82.
74 Tierie, op. cit., 22. Metius is an example of one who combined astronomy and surveying.
75 Ibid, 25.
76 Ibid, 50–1. Tierie suggests that Huygens introduced the camera obscura to, at least, artists Gheyn and Torrentius. Huygens became a politically central figure in the young Dutch Republic who was in correspondence with people all over Europe. He personally knew many of the other leading artists of his time (in fact, he employed them for one project or another, including Rembrandt, Rubens, Lewins, Van Campen, Bloemart, etc.).
77 Baigrie suggests another connection: that Rembrandt, who painted The Anatomy Lesson of Dr. Tulp (see Figure 15.1), attended some of Dr. Tulp's lectures and that since these were both public and popular, Descartes might have attended one or more of them also. Baigrie admits, however, that there is no evidence that Descartes attended any of Dr. Tulp's lectures or that Descartes and Rembrandt ever met.
78 AT x. 152. Descartes' 'tour' in the army of Prince Maurice actually raises several interesting possibilities. In addition to what he lists here he may have studied surveying (map-making), engineering, particularly hydraulics (how to ensure a water supply for fortifications was important), and/or cryptography.
79 AT x. 216. Perspective, including sometimes anamorphosis, was used in the artistic construction of gardens. Baltrusaitis writes: 'Gardens can be arranged in such a way that, viewed from a given point, the trees and plants are transformed into animals which look as though they are painted in a picture; towns likewise can be built up of "living" figures.' (Baltrusaitis, 81). He gives examples from Bracelli (1624) and Bettini (1642), among others. See Baltrusaitis, ch 6.
80 Pierre Borel, *A summary or compendium of the life of the most famous philosopher Renatus Descartes* (London, 1670).
81 AT iii. 695.

20 From sparks of truth to the glow of possibility

Peter Schouls

In his mid-twenties Descartes, contrasting imagination and reason, juxtaposed poets with philosophers in a manner more favourable to the former than the latter:

> It may seem surprising to find weighty judgements in the writings of the poets rather than the philosophers. The reason is that the poets were driven to write by enthusiasm and the force of imagination. We have within us the sparks of knowledge, as in a flint: philosophers extract them through reason, but poets force them out through the sharp blows of imagination, so that they shine more brightly.[1]

Sparks may arrest attention for a moment, but as the fiery particles cool they quickly lose their brilliance. They are unconnected moments of light, one not necessarily leading the eye to another. Some years later, the truth of poetic imagination becomes just that for Descartes: transitory brilliance which reason cannot place in a coherent system to serve as guide for life. His admiration for the poet's imagination is that of the thinker who had not yet developed rules to discipline imagination into a source for reason to draw on in seeking and finding scientific truth. Such a disciplined imagination generates the glow of possibility without which there is no subsequent light of a rational scheme with the supposed potential to brighten humankind's path through applications of scientific truth. It is the mature Descartes' conviction that only the steady flame of scientific, not the evanescent sparks of poetic, truth allows for the possibility of human progress. Poetry, says a forty-year old Descartes, 'has quite ravishing delicacy and sweetness', but is to be placed among the subjects which 'it is good to have examined . . . in order to know their true value and guard against being deceived by them'.[2] Indeed, the sparks of poetic truth 'shine more brightly' than the glow of imaginative scientific possibility; but Descartes believes that only this glow has the potential to become the steady light of science by which all sparks pale and which dispels the darkness to which poetry brings but fleeting relief.

Nevertheless, disciplined imagination retains its affinity with that of poets. If imagination's truth is truth through fiction, in some sense fiction plays its role in all of Descartes' work. If I can demonstrate the latter, then one conclusion to be drawn is that – at least in Descartes' work – poetry and philosophy, art and science share one common root in the indispensable role of imagination. This is a conclusion I will in fact draw, though as a subsidiary point.

My major point is that, just as there is, for Descartes, a bodily, or corporeal, and an intellectual memory, so there is a corporeal and an intellectual imagination. Commentators tend to be aware of the first three but, until very recently, there was almost complete ignorance about the last.[3] The assumption may have been that Descartes believed it best to relegate intellectual imagination to poets in the production of their sparks. In fact, however, Descartes regarded intellectual imagination as the human capacity necessary for the generation of all systematic knowledge. Two of its functions are that in philosophy and science it is the source of the hypotheses without which these disciplines cannot be developed, and in the link between philosophy and applied physics it is the source of symbols. I shall deal with these two functions in turn.

Intellectual imagination plays a more extensive role than does its corporeal counterpart. Descartes is often at pains to restrain the latter. On the other hand, the products of intellectual imagination are, under specific circumstances, themselves judged as useful or not by means of corporeal imagination. Let me illustrate these abstract statements by focusing on the role of imagination, first, in Descartes' *Meditationes* (here we will see intellectual imagination as the source of hypotheses and corporeal imagination – at least until the Sixth Meditation – as totally restrained) and, second, in one of his most successful scientific works, the *Géométrie* (which will illustrate the intellectual imagination's role as origin of both hypotheses and symbols, and will introduce corporeal imagination as mediator between abstract or symbolic thought and concrete possibility).

The *Meditationes*

Although intellectual imagination plays a dominant role in the first three of the Meditations, the ever-growing literature on them hardly mentions it.[4] When, in them, Descartes refers to the imagination by name, he makes it very clear that at this stage of the argument recourse to imagination is illegitimate and, if nevertheless persisted in, will derail us from the track leading to the required foundation for all systematic knowledge. However, this dismisses corporeal imagination, the imagination which images or pictures. Corporeal imagination both enters and exits the stage in the seventh paragraph of the Second Meditation:

> What else am I? I will use my imagination (*imaginabor*). . . . I know that I exist; the question is, what is this 'I' that I know? If the 'I' is under-

> stood strictly as we have been taking it, then it is quite certain that knowledge of it does not depend on those things of whose existence I am as yet unaware; so it cannot depend on any of the things which I invent in my imagination (*quae imaginatione effingo*).

The 'things which I invent in my imagination' (says Descartes in the rest of this paragraph) are: that I am 'the human body', or 'some thin vapour which permeates the limbs'; but, he says, 'these are things which I have supposed to be nothing'. It is that supposition which, near the end of the First Meditation, was elevated to the guiding principle of the argument: 'I . . . admit that there is not one of my former beliefs about which a doubt may not properly be raised. . . . So in future I must withhold my assent from these former beliefs just as carefully as I would from obvious falsehoods, if I want to discover any certainty.' Hence I must live in suspension, accepting that it may be the case that 'there is absolutely nothing in the world, no sky, no earth, no minds, no bodies'. If there are 'no bodies', it is no use to try and answer the question 'What else am I?' through enumerating bodily things. And although I know that I am 'a thinking thing', I must for the time being accept that there are 'no minds', at least to the extent that 'mind' would include a reference to corporeality – as it does in the mental function of corporeal imagination. Therefore the answer to the question 'What else am I?'

> . . . cannot depend on any of the things which I invent in my imagination . . . for imagining is simply contemplating the shape or image of a corporeal thing [and] . . . all such images and, in general, everything relating to the nature of body, could be mere dreams. . . . I thus realize that none of the things that the imagination enables me to grasp is at all relevant to this knowledge of myself which I possess, and that the mind must therefore be most carefully diverted from such things.[5]

So corporeal imagination is shooed off the metaphysical stage, not to be allowed its come-back until the Sixth Meditation.[6]

But none of this entails the non-existence of intellectual imagination. Quite the contrary: it allows the possibility of its existence precisely because it is non-corporeal. Let me now demonstrate that it exists at the very time when corporeal imagination is ruled out of existence, in fact, is the cause of this presumed non-existence as well as of the presumed non-existence of 'world', 'sky', 'earth', 'minds', 'bodies' – but also of the presumed existence of 'God' as an evil deceiver. It is best to begin with the latter.

The idea of God cannot be grasped through corporeal imagination.[7] Although we cannot picture God, we can conceive or think of God. We may extrapolate and say that the idea of a deceiving God or evil demon is not accessible through corporeal imagination either, for this demon has all and only the characteristics of God, except that supreme goodness is replaced with 'the utmost power and cunning' (*summe potentem et callidum*) which makes him 'malicious' in that he is always deceiving us.[8] However, the deceiving God is not known to exist but is supposed or imagined to exist. His existence is a hypothesis, introduced in the First Meditation in order to push doubt to its most extreme limits so that, if any certainty is encountered during this process, it will be absolutely unshakeable.

Descartes explicitly labelled the deceiving God's existence as a hypothesis, and it is important to note what he said about it. In response to a question from Buitendijck,[9] he wrote:

> Once the true God is clearly known . . . it is not possible for the human mind to attribute anything false to him, as I have explained in my Meditations . . . But the case is not the same with . . . God, if he is known only in a confused way. To attribute . . . something false as a hypothesis can be either good or bad, depending on whether the purpose of framing such a hypothesis is good or bad. For what is thus imagined and attributed hypothetically is not thereby affirmed by the will as true, but is merely proposed for examination to the intellect . . . Thus, take the case of someone who imagines a deceiving god – even the true God, but not yet clearly enough known to himself or to the others for whom he frames his hypothesis.

In the opening Meditations, either God is clearly known to Descartes and he frames his hypothesis for others, or God is not yet clearly enough known to himself. Whatever the case, it is not reason which provides the hypothesis, but imagination.

Why cannot reason be its source? Suppose we did take reason to be its origin. This would be going against the grain of the First Meditation's argument, where it has just been decided that no credence may be given to any of reason's utterances. In other words, circularity would erupt where no-one has ever surmised its lurking. Second, if we were to disdain circularity by placing our faith in reason we would, though prematurely, reintroduce the faculty which – apart from the metaphysical doubt of the *Meditationes* – Descartes has always held to be infallible. In words from the *Principia Philosophiae*, reason 'cannot incline to falsehood', it 'can never encompass any object which is not true in so far as it is indeed encompassed by this faculty'.[10] Now the hypothesis about the deceiving God shares with any hypothesis the characteristic that we do not yet know it to be true and that it may be false; moreover, the hypothesis will turn out to be false because contradictory.[11] Contradictory statements can be imagined and remembered, but not understood. We can understand that a statement is contradictory, but we cannot understand the contradictory statement. Thus, apart from the problem of circularity, reason cannot be its source because it cannot 'incline to' or 'encompass', let alone be the source of, contradiction.

But if, in the First Meditation, it is not reason which 'supposes' the existence of the deceiving God, then it must be either intellectual memory or intellectual imagination. It must be 'intellectual' if only because anything corporeal is there stipulated to be non-existent. Of the two, memory is to be eliminated, for Descartes consistently holds it to be incapable of originating anything.

This, then, is the situation. Reason is incapable of proposing the hypothesis of the deceiving God's existence because it cannot be the source of any hypotheses.[12] Corporeal imagination cannot be its source because (i) the demon is as non-corporeal as is 'the true God' and therefore cannot be corporeally imagined,[13] and (ii) since the hypothesis rules corporeality to be non-existent no use can be made of corporeal imagination during the time the hypothesis is in force. And with memory, strictly speaking, incapable of originating anything, the only power that can account for this hypothesis is intellectual imagination.

In the *Second Set of Replies*, Descartes comments on the argument as it stands at the end of the Third Meditation:

> Since God is the supreme being, he must also be supremely good and true, and it would therefore be a contradiction that anything should be created by him which positively tends towards falsehood. . . . Hence you see that once we have become aware that God exists (*postquam Deum existere cognitum est*) it is necessary for us to imagine (*fingamus*) that he is a deceiver if we wish to cast doubt on what we clearly and distinctly perceive. And since it is impossible to imagine that he is a deceiver, whatever we clearly and distinctly perceive must be completely accepted as true and certain.[14]

This is at the end of the Third Meditation, where reason has weathered the whirlwind of metaphysical doubt and is legitimately re-instated as absolutely trustworthy. Hence, when reason cognizes God as existing, it must cognize him as non-deceptive. As long as we do that, it is at the same time 'impossible to imagine that he is a deceiver'. But at the beginning of the *Meditationes*, with reason itself requiring validation before we know 'whether there is a God, and, if there is, whether he can be a deceiver', 'it seems that I can never be quite certain about anything else'. I can then 'never be quite certain', that is, I have no trustworthy cognitions, because of the regime of a hypothesis which is the product of intellectual imagination.

Descartes' extremely careful language throughout the first three Meditations fully supports this conclusion. The deceiving God is introduced in the First Meditation's ninth paragraph with the sentence 'How do I know (*scio*) that he has not brought it about that there is no earth . . .?' Since I do not know, I am free to focus on the hypothesis – which Descartes then does in the words 'I will suppose (*supponam*) therefore . . . some malicious demon of the utmost power and cunning'. The Second Meditation finds its point of departure here. Its first two paragraphs state that 'anything which admits of the slightest doubt' – as the French version has it: '*en quoy je pourray imaginer le moindre doute*' – 'I will set aside', and 'I will suppose (*suppono*) then . . . that nothing is certain'. The 'Archimedean point' is reached while this supposition is in force, and it remains in force immediately after: 'But what shall I now say that I am, when I am supposing (*suppono*) that there is some supremely powerful and . . . malicious deceiver?' says its sixth paragraph. In the fourth paragraph of the Third Meditation this is, again, made the point of departure: 'And whenever my preconceived belief (*praeconcepta*) in the supreme power of God comes to mind, I cannot but admit that it would be easy for him, if he so desired, to bring it about that I go wrong even in those matters which I think I see utterly clearly with my mind's eye.'

The very fact of the imagination's keeping this hypothesis before the understanding is what allows for progress in establishing the sought-for 'stable and lasting' foundation for the sciences. Descartes needs imagination to introduce hypotheses. Without hypotheses there is no way of establishing the metaphysical foundation for science, let alone developing the sciences to be erected on this foundation. At this metaphysical foundation the imagination in question is intellectual, not corporeal. With the trustworthiness of reason, of sense and of memory in question, there remains no way of proceeding except by intellectual imagination. Where there is no certainty, that to which by definition there never attached certainty to begin with – namely, intellectual imagination – may be used without fear of circular argumentation.[15]

The use of intellectual imagination in this metaphysical argument is not essentially different from its employment in any other situation where there is an attempt to develop knowledge. The problem Descartes here sets himself is: to find a firm foundation for the sciences. The traditional 'grounds' for certainty in science are reason and sensory experience. Can either of these be trusted without a shadow of doubt, so that an absolutely certain foundation can be established? Rational arguments from illusion and delusion cast some doubt on sense, which is therefore disqualified. But we must go beyond reason to cast doubt on reason. Thus intellectual imagination enters, forced to do so by the knowledge we already have which, in this case, is knowledge that we do not know but want to discover whether absolute certainty is achievable. Hypotheses, if they are legitimate, must come in a context of genuine doubt. They must at least prima facie answer a genuine question. And that is what this hypothesis does. Re-read part of what I quoted from Descartes' letter to Buitendijck, and at the end add a few phrases which I earlier omitted:

> Take the case of someone who imagines a deceiving god – even the true God, but not yet clearly enough known to himself or to the others for whom he frames his hypothesis. Let us suppose that he does not misuse this fiction for the evil purpose of persuading others to believe something false of the Godhead, but uses it only to enlighten the intellect.

Descartes certainly believed that the hypothesis about the malicious God 'enlightened the intellect'. It led him to his 'Archimedean point' from which, to his full satisfaction, he showed the absolute trustworthiness of reason. That placed him in the position which, he believed, enabled him to explain the problem of error and give a rule which, if scrupulously followed, would make error a thing of the past. And it put him in the position to argue for the conditions under which we can trust the senses and memory. What more can one ask of a hypothesis at this stage of one's thinking, if it is seen as allowing one 'to demolish everything completely' and then placing one in the position from which to 'start again right from the foundations' without ever having to go wrong?

At this point I draw the conclusion that, for Descartes, truth is reached through fiction.[16] In the first three of the Meditations this is the fiction of the deceiving God. Thus, philosophers and poets both depend on imagination; and – perhaps going beyond what Descartes would be willing to acknowledge – one might say that in Descartes' use of imagination we see the common root of literature and philosophy, of humanities and sciences.

If we were to stress Descartes' rationalism to the extent that we allow no source for truth except reason (in this way disregarding the roles Descartes assigns to imagination as well as to sensation), one might take the idea of this common root not to fit as part of the position of the progenitor of modern philosophy and of a good deal of modern science. But, as much recent scholarship has established, it would be wrong so to stress the role of reason in the Cartesian system. Moreover, is not the relation between imagination and reason as it finds expression in tentativeness and certainty, hypothesis and theory, fiction and fact, a relation found in all thinking which progresses from the unknown to the known, in all mental activity open to questions and driven by wonder? Does not this relationship characterise (for example) Plato's *Theaetetus* and contemporary cancer research as much as it does Descartes' *Meditationes*? Which is not to say that, in the *Meditationes*, there is not something very special about Descartes' use of fiction: he there used fiction to an extent and with an aim different from his predecessors and successors. In the attempt to doubt whether one doubts, or in the attempt to imagine that one might not be imagining when one believes oneself to be imagining, Descartes meant to extend this fiction to absolutely everything, itself included.

But that was my story on a different occasion.[17] What I want to do in my remaining pages is: to see intellectual imagination at work in the science of geometry, and to see it judged there through the use of corporeal imagination.

The *Géométrie*[1]

Classical geometry becomes the novel discipline of analytic geometry when Descartes brings a new mode of algebraic thinking to a traditional way of geometrical thinking. As abstract concepts, the objects of Descartes' analytic geometry have no necessary relation to physical existence; and their nature is determined, not through properties taken to be exclusively their own, but through the conceptual relations of the intellectual context in which they function. Although all of these objects are imaginable, many of them are not imageable. Even of those that can be imaged it must be said that they differ from the objects of classical geometry. For traditional geometricians, the senses apprehended lines and figures as particular existences with particular proportions; for Descartes, they are conceived as presentations of general items so that the visualised images or sensed objects retain their generality. Thus, in Descartes' geometry lines and figures no longer are traditional geometrical objects in their own right.

There are various aspects of the *Géométrie* in terms of which we can discuss the role of intellectual imagination. One of these is the use of hypotheses in the technique of 'assuming the problem to be already solved' by (a) supposing an unknown but potentially knowable quantity, or by (b) supposing something unknown which cannot possibly come to be known (as in the postulation of 'negative roots'). A second is in Descartes' use of symbols. I shall deal with (i) hypotheses and (ii) symbols in turn. The second of these will allow me to relate intellectual and corporeal imagination in the passage from theory to practice.

Hypotheses

Intellectual imagination plays its role in geometry by assuming the problem to be already solved through supposing an unknown but potentially knowable quantity. As in the *Meditationes*, so in the *Géométrie*, we meet the terms which Descartes employs as indicators for the presence of intellectual imagination, as in 'if we wish to solve some problem, we should first of all consider (*considerer*) it solved'.[19] and 'I assume (*suppose*) the problem to be already solved'.[20] The supposition, in these cases, is the assumption of a hypothesis in the form of an equation or a set of equations, in which we work with symbols of some of which we know the value and of some of which we do not, and in which the unknown values are to be determined through comparison with or relation to the symbols whose values are known. The act of assuming the problem to be already solved occurs in introducing the symbols for which we do not yet have values, and the actual solving of the problem (if it can be solved) occurs in relating these symbols to those for which we do have values.

These assumptions may introduce not just symbols representing unknown quantities but, as well, symbols which indicate whether such quantities are positive or negative. The assumption usually involves more than a single supposition. There is a single supposition only in those cases where we can imagine no more than a single possible solution to a problem. In most cases, various solutions are imaginatively possible, and each of these possibilities must be enumerated as one of the suppositions. When he introduces these, Descartes in some instances uses a form of the word 'imagine' and sometimes of 'suppose,' but both cases are clearly of the same kind.

In the following passages the intellectual imagination's presence is indicated through the use of some form of supposer. In solving geometrical problems by means of equations, 'we must find as many such equations as we assume (suppose) there to be unknown lines'.[21] '[T]he equation by which we look for the quantity x or y or another such quantity – assuming (*en supposant*) [the lines] PA and PC are known. . . .'[22] '[T]he signs $+$ and $-$ can be assumed (*suppose*) to be however we wish. . . .'[23] '[T]he invention of assuming (*l'invention de supposer*) two equations of the same form, in order to compare separately all the terms of the one with those of the other, and so to get several equations from one . . . can be used in an infinity of . . . problems.'[24] '[I]n each equation there can be as many different roots (that is, values of the unknown quantity) as the unknown quantity has dimensions. For example, if we assume (*suppose*) x equal to 2. . . .'[25] 'And if, without knowing the value of the roots of an equation, we wish to increase or diminish it by some known quantity, it is only necessary to assume (*supposer*), in the place of the unknown quantity [x], another which is greater or lesser than this unknown quantity by the given number.' (For example, if we want to increase x by 3, then x comes to be substituted by y, where $y - 3 = x$).[26]

These various uses of *supposer* mark the presence of intellectual imagination, for each of these examples introduces an unknown but hypothetically posited quantity symbolically represented, or involves experimental manipulation of the positive or negative value of this hypothetical quantity. In each of the cases there is the expectation that – through the relationships holding in the equation of which the unknown quantity is a part – the unknown quantity will have its symbolic representation replaced with a specific and known quantity. These instances of symbolic representation are analogous to what happens when hypotheses are verified in the physical sciences: both symbol and hypothesis disappear qua symbol and hypothesis, in that both become known parts of the relevant system.

There are, however, other cases of the use of *supposer* or of *imaginer* where, in a crucial respect, the outcome is different. Here, intellectual imagination supposes unknown entities some of which cannot come to be known. This difference allows us the clearest encounter with intellectual imagination in the *Géométrie*. The cases in question are some of those in which Descartes introduces roots:

> For the rest [note that] the true roots, as well as the negative ones, are not always real, but sometimes only imaginary (*imaginaires*); that is, while we can always conceive (*imaginer*) as many roots for each equation as I have stated, still there is sometimes no quantity corresponding to those we conceive (*qu'on imagine*). Thus, although we can conceive (*qu'on imagine*) three roots in the equation
>
> $$x^3 - 6x^2 + 13x - 10 = 0$$
>
> there is nevertheless only one real root, 2, and no matter how we may augment, diminish, or multiply the other two, in the way just explained, they will still be imaginary (*qu'imaginaires*).[27]

The concept of roots which are 'sometimes only imaginary', so that 'there is sometimes no quantity to those we conceive (*qu'on imagine*)', serves my argument in two ways. First, it illustrates the presence of intellectual imagination: the imaginary roots for which there is 'no quantity' are non-representable non-intuitable objects arising out of purely structural considerations.[28] Second, the concept of such roots can be kept in mind as corroboration for a point I will make when I deal with the role of symbols: it illustrates that Descartes frees mathematical science from its Greek understanding in which the objects of mathematical thought were always identifiable quantities.

The passage just quoted contains the conclusion of a line of argument which started a few pages earlier in Descartes' text. If we backtrack to these earlier pages, this will further confirm the role of intellectual imagination:

> I must say something in general about the nature of equations – that is, about sums composed of many terms, partly known and partly unknown, some of which are equal to others, or rather, all of which taken together are equal to nothing, for it is often best to consider them in this way. Understand, then, that in each equation there can be as many different roots (that is, values of the unknown quantity), as the unknown quantity has dimensions. For example, if we assume (*suppose*) x equal to 2, or else $x - 2$ equal to zero; and again $x = 3$, or else $x - 3 = 0$, then by multiplying these equations, $x - 2 = 0$ and $x - 3 = 0$, by each other, we will have $x^2 - 5x + 6 = 0$, or else $x^2 = 5x - 6$, which is an equation in which x has the value 2, and simultaneously has the value 3. And if again we make $x - 4 = 0$, and multiply this by $x^2 - 5x + 6 = 0$, we will have $x^3 - 9x^2 + 26x - 24 = 0$,

> which is another equation in which x, having three dimensions, also has three values, which are 2, 3, and 4. But it often happens that some of these roots are negative, or less than nothing.[29]

If some of these negative roots are non-intuitable but still part of the discipline, they must be imaginable. We then have the power of imagining them, but not corporeally so. The fact that we cannot corporeally imagine them is reflected in Descartes' statement that these roots cannot function as entities which allow for geometric construction: 'We know . . . that the four roots of the equation . . . are imaginary; and that the problem for which we discovered this equation is plane by nature, but that it cannot in any way be constructed, because the given quantities cannot be added.'[30] The importance of the fact that an entity cannot be imaged or constructed on paper I shall leave for (ii), the use of symbols, which is the other aspect of the *Géométrie* through which we can approach the role of intellectual imagination.

Symbols

Descartes contrasts his procedure in mathematics with that then still current: 'Arithmeticians usually represent individual magnitudes by means of several units or by some number, whereas . . . we are abstracting just as much from numbers as . . . from geometrical figures . . . or from any matter whatever.'[31] The resulting abstract entities then become symbols such as a, b and c for the known quantities, x, y and z for the unknown quantities,[32] as well as their relevant squares, cubes, etc. represented by a^2, x^3, etc.[33] These symbols, in turn, come to function in relations of the kind called 'equations'. It is these equations which now become the thinker's objects. They are objects meant to be radically free from any physical interpretation, objects which give entry into a mathematical world in which 'geometry' and 'algebra' become interchangeable modes of thinking.

In these equations the symbols are mathematically interpreted so that they allow for the kinds of manipulation familiar from arithmetic, namely, addition, subtraction, multiplication, division, and extraction of roots. For these symbols and for their manipulation in equations we depend on imagination.[34] The imagination in question is intellectual rather than corporeal for, as we already noted, the symbols arose in the first place through abstraction from 'matter', 'geometrical figures', and 'numbers'. And it is imagination rather than reason, for the equations in which these symbols function contain unknown quantities, namely, some of these symbols themselves.[35] The fact that these symbols are entirely abstract allows for their use as magnitudes in general in all sorts of proportions, and their abstract nature allows for ratios between or among entities which are not perceptible or imageable entities, like a^4, a^5 or, in general, a^n.

The ratios among these entities depend entirely on the rules of algebra; hence both these entities and their relations are free from the constraints of sensation or corporeal imagination.

This use of symbols in analytic geometry places Descartes in a situation far removed from that of the ancient geometers. For them diagrams, that is, imageable or sensible data, were the loci in which discoveries are made. For Descartes, geometrical discoveries are made in the first place in the abstract realm of algebra. This priority of the abstract has as a consequence that when some of these discoveries allow for their representation on paper, then what is conveyed through these diagrams is itself universal. Thus a Cartesian geometrical diagram never conveys relations which hold only in the pictured instance. The fact that its construction was governed by an algebraic equation insures that it is never one of a kind.

At the end of his *Géométrie* Descartes makes it quite clear why the new geometry cannot be restricted to what may be corporeally imagined or constructed with ruler and compass. In its final paragraph he comments on the fact that he has provided a way of solving all[36] plane and solid problems in geometry, and then adds that 'we have only to follow the same method in order to construct all problems to an infinite degree of complexity. For in the matter of mathematical progressions, once we have the first two or three terms, it is not difficult to find the others.' The degree of generality in the phrase 'construct all problems to an infinite degree of complexity' implies that the equations of analytic geometry must be considered independently of the possibility of their being corporeally represented in the pictures of imagination or the on-paper diagrams of classical geometry. With respect to geometrical problems which are one, two, or *n* degrees more complex than those of solid geometry, visualisation or spatial construction is impossible. Three-dimensional space determines the limits of human ability corporeally to imagine and sensibly to construct. Descartes refuses to accept these limits as boundaries for his geometry. And when he writes about those elements of his geometry which can be neither pictured nor constructed, he writes about them being 'imagined'. The conclusion that this is non-imaging non-corporeal imagination is inescapable. Thus intellectual imagination is crucial to this new discipline which Descartes put on the map of science. I will now conclude with some comments about the role of corporeal imagination in this context set by intellectual imagination in geometry.[37]

There is no dearth of diagrams in Descartes' *Géométrie*. Diagrams can be pictured in the corporeal imagination and physically constructed on paper with ruler and compass. These diagrams illustrate the greater utility of Descartes' approach as compared to that of the ancients, and allow the passage from abstract thought to concrete possibility. I shall stress the second of these points, and about the first say only the following. Diagrams demonstrate the utility of Descartes' approach through illustrating the solution of problems which had frustrated classical geometry. In this process they illustrate the power of his method. And since all these problems are solved by a single procedure – by the method which is itself a functional definition of reason – they are now all part of the same rational scheme. Thus Descartes believes that classical geometry itself has for the first time in history been made into a true science.

More important for my topic, however, is that diagrams play a role in the transition from theory to practice. The abstract thinking required for pure science is, for Descartes, never to be an end in itself; the time devoted to it, though necessary, should remain minimal. This sort of thinking has instrumental value only, in that it serves to lay the foundations for mastery over nature. It is as foundation for practical mastery that the geometrical diagram, hence corporeal imagination, plays a necessary role.

Diagrams introduce a double relativisation in Descartes' *Géométrie*: a relativisation *of* diagrams and a relativisation *through* diagrams. First, relativisation of diagrams allows for geometrical insight to extend beyond the confines of Euclidean space; thus Descartes passes beyond classical geometry. Second, diagrams in turn serve to indicate the extent to which Descartes' analytic geometry is potentially relevant to the physical world in which we live and so they relativise the new geometry. Diagrams reveal that not all of this analytic geometry can serve applied science, and they help to determine the nature and extent of the possible linkage between pure and applied science. In other words, Descartes' geometry needs diagrams – requires corporeal imagination – as a necessary complement. This is because pure geometrical thought reveals a realm some of which is possible in our world and some of which transcends such possibility. Pure geometry by itself does not identify the possible, or the possibly actual, configurations of our physical world.[38]

The matter of priority is, however, crucial. It is reason and intellectual imagination, not corporeal imagination or sensation and hence not the diagram, which determines the contents of geometry.[39] Ideas of the intellect are logically prior to the images of corporeal imagination.[40] As long as we deal with the development of this science, visible illustrations may play no role hence corporeal imagination must be kept at bay. But once the science (or a distinct part thereof) has been developed, illustrations become crucially important. For since geometry is meant to be developed as a basis for the sciences which promise their dividends in their utility, it becomes necessary to illustrate the physical applicability of geometry to the extent that it has such applicability. The geometrically constructible diagram is needed as intermediary between pure thought and practical application.

Corporeal imagination plays a crucial role when, in imaging the analytic relationships stated in an equation, it produces an item which is both intellectual and corporeal. We can therefore speak about corporeal imagination as 'mediator'.[41] It can play this mediating role because, although both understanding and corporeal imagining are mental functions, they are quite different mental functions. As we read in the Fifth Set of Replies,

> the powers of understanding and [corporeal] imagining do not differ merely in degree but are two quite different kinds of mental operation. For in understanding the mind employs only itself, while in imagination it contemplates a corporeal form. And although geometrical figures are wholly corporeal, this does not entail that the ideas by means of which we understand them should be thought of as corporeal.[42]

Therefore, when through the use of symbols we abstract from specific 'geometrical figures', 'numbers', and 'from any matter whatever'[43] and so transcend the boundaries of Euclidean space and deal with 'magnitudes in general', there is nothing to prevent us subsequently from determining which of these 'magnitudes in general' can 'also be ascribed to' certain 'species of magnitude'.[44] The fact that nothing prevents us from this activity allows for the realisation of the duty Descartes ascribes to those who develop pure science: they must make their abstract thought serviceable to achieving understanding of practical reality.

This task can be achieved because of the nature of corporeal imagination and the role which this nature makes it possible for it to play. When, through corporeal imagination, the mind images the relationships holding in an algebraic formula, the image which results is a generalised image and, as such, differs from the particular image received through sensation. In this process of imaging, the passivity and haphazardness of sensation has come to be replaced by the activity and scientific control of the intellect. Imagination now no longer represents what our eyes have fortuitously come across in the physical world, but presents what our intellect has inscribed from within. In both cases, the image is a physical entity, for this imagination is corporeal. In both cases, therefore, there is embodied extension. But what used to be (as in pre-Cartesian geometry) embodied extension, over whose configurations the intellect had limited or no control, is now embodied extension, over whose configurations the intellect – being its author – has full control. Its authorship consists in the fact that these now visible configurations arose through the intellect's imaging the relations holding in the algebraic equations which it has itself both constructed and solved.

The preceding paragraphs indicate both the considerable coalescence of my exposition with that of Dennis L. Sepper's chapter in this volume, 'Figuring things out', and the point at which I go beyond the position he there adopts. Coalescence comes about through our agreement that diagrammatic instantiation allows the scientist passage from theory to practice and so provides the foundation for the relevance of theoretical solutions to problems in the world in which we live. For both of us, therefore, imagination becomes crucial to understanding Descartes' thought – both of Descartes the young and Descartes the mature thinker. The point on which there is some disagreement is that for Sepper, in both the *Regulae* and the *Géométrie*, algebra remains subordinate to geometry as a memory aid which allows us schematically to keep track of geometrical problems. This is no doubt one of its functions. But a more important function is that algebraic representations indicate various realms of possibility, while geometric or imagistic figuration indicates possibilities, or actualities, in the specific realm which constitutes the human sensible world. Sepper, in other words, has no space for the double role of relativisation which I ascribe to Descartes' figuration.

Through corporeal imagination Descartes means to pass from the glowing embers of the imaginatively possible to the blazing fire of the scientifically understood actual. The scientifically understood physically actual image traced in the corporeal imagination is to guarantee that this image can be made actual as intelligible–sensible object in the physical context of the being in whose imagination this image exists. In the process, Descartes has taken a position far removed from that which allowed him admiration for the sparks which the sharp blows of enthusiastic poetic imagination forces from the flint of human nature. These sparks no longer shine more brightly than the systematic truth which philosophers and scientists extract through reason aided by disciplined imagination.

Much of modern Western philosophy and science is widely acknowledged to be Descartes' legacy. This legacy includes the troublesome divide between poetry and philosophy, arts and sciences. The two sides of the divide have a common root in imagination – and one of history's ironies is that Descartes' work demonstrates this.[45]

Notes

1 AT x. 217.
2 AT vi. 5–6.
3 The recent exceptions are Véronique M. Fóti, 'The Cartesian imagination', *Philosophy and Phenomenological Research* vol. 46 (1986), 631–42; and Dennis L. Sepper, 'Descartes and the eclipse of imagination, 1618–1630', *Journal of the History of Philosophy* vol. 27 (1989), 397–403, 'Ingenium, Memory Art, and the Unity of Imaginative Knowing in the Early Descartes', in Stephen Voss, ed., *Essays on the Philosophy and Science of René Descartes* (New York, 1993, 142–61), and *Descartes's Imagination* (Berkeley, 1996). In a book now nearing completion, I give extensive grounds for the judgments that (a) Descartes needed intellectual imagination and was quite conscious of this need (b) as he drew on intellectual imagination in his development of metaphysics and pure physics; (c) and even though he did not use the phrase 'intellectual imagination' he used the synonyms which philosophers still employ today when they refer to imageless imagination and its role in philosophy and science.

4 This in contrast to work done on the corporeal imagination. For a valuable example of the latter, see J.J. MacIntosh, 'Perception and imagination in Descartes, Boyle and Hooke', *Canadian Journal of Philosophy*, vol. 13 (1983), 327–52.

5 In the French version of the *Meditationes*, 'such things' is replaced by '*cette façon de conceuoir*'. The fact that it says '*façon*' rather than '*méthode*' is important. Descartes uses *méthode* to refer to his general method of procedure. This method has 'helps' in sensation and corporeal imagination. But these helps cannot be used until the general method has itself been validated – and that takes place in the first three of the *Meditationes* (part of this story is that with method as the functional definition of reason, the validation of reason is at the same time a validation of method). Hence, at this stage, if 'f*açons*' are allowed to play a role they do so illegitimately. Thus Descartes' technical use of terms here supports my interpretation. (For the technical uses of '*méthode*' and '*façon*', see Schouls, *The Imposition of Method* (Oxford 1980) 63–75.)

6 There, Descartes stresses once more that it is not part of the 'I' which we know to exist in the Second Meditation: 'I find in myself faculties for certain special modes of thinking, namely imagination and sensory perception. Now I can clearly and distinctly understand myself as a whole without these faculties. . . .' (AT vii. 78).

7 See the *Discours* as helpful background material for this part of the argument. In a passage in which 'imagination' is aligned with sensation, hence is corporeal, we read: 'Thus I conclude that it is at least as certain as any geometrical proof that God, who is the perfect being, is or exists. But many are convinced that there is some difficulty in knowing God. . . . The reason for this is that they never raise their minds above things which can be perceived by the senses: they are so used to thinking of things only by imagining them (a way of thinking specially suited to material things) that whatever is unimaginable seems to them unintelligible. This is sufficiently obvious from the fact that even the scholastic philosophers take it as a maxim that there is nothing in the intellect which has not previously been in the senses; and yet it is certain that the idea of God [has] never been in the senses.' (AT vi. 36–7).

8 That it is God and not some interloping minor devil we must here think of is clear enough from statements to be introduced later; in the meantime, these sentences from *Principia* I, art. 5 will help to establish that point: '. . . we have been told that there is an omnipotent God who created us. Now we do not know whether he may have wished to make us beings of the sort who are always deceived even in those matters which seem to us supremely evident.'

9 AT iv. 64.

10 These phrases are from the *Principia*, I art. 43 (AT viii-A. 21); and I art. 30 (AT viii-A. 16) respectively.

11 Descartes' comment about this hypothesis in his conversation with Burman is that 'What the author says here is contradictory, since malice is incompatible with supreme power'. (AT v. 147) See also AT v. 150–1: '*et si fas est dicere malignum . . .*' '*Addito illa restrictio ibi ideo, quia auctor contradictoria loquitur . . .*' John Cottingham, in his *Descartes' Conversation with Burman* (Oxford, 1976, 9) renders it as 'and, if it is permissible to say so, malicious?' 'The restriction is added here because the author is saying something contradictory. . . .'

12 Hypotheses are pre-judgements, pre-conceptions, and as such cannot be the work of reason. As we shall see, Descartes' language throughout the Meditationes remains careful in this context.

13 See here Descartes' *Reply* at AT vii. 181: 'Here my critic wants the term "idea" to be taken to refer simply to the images of material things which are depicted in the corporeal imagination; and if this is granted, it is easy for him to prove that there can be no proper idea of an angel or of God.'

14 AT vii. 144.
15 More needs to be said about this part of the argument than I can here state. There is no imaginative activity without an exercise of freedom and, since Descartes questions not only the existence of reason but also the existence of freedom in the first three Meditations, we do not know whether we are in fact imagining when we think we are imagining or, in general, whether we are in fact active (rather than passive) when we experience ourselves to be active. I developed this interpretation of Descartes' argument in my 'Human Nature, Reason, and Will in the Argument of Descartes's *Meditations*' in John Cottingham, ed., *Reason, Will and Sensation* (Oxford, 1994), 159–76
16 This conclusion overlaps with that of Dalia Judovitz in 'Derrida and Descartes: Economizing Thought', in Hugh J. Silverman, ed., *Derrida and Deconstruction* (London, 1989), 20–58; the following quotations are from pp. 41–2, 47, 51, and 57 respectively. She writes that 'her study will address one of the major paradoxes of Cartesian philosophy as a discourse that attains certitude through the use of fiction, in order to posit truth as an entity beyond fiction'. Her use of 'certitude' introduces the *cogito*, and her use of 'fiction' points to the imagination: 'the truth of the *cogito*'s existence is here established through the exercise of an impossible fiction, through a rhetoric of negation whose truth is based on the totalizing character of fiction . . .' by means of 'the fiction of the evil genius'. This, she believes, is the first time in the history of philosophy that truth is achieved through fiction: 'the *Meditations*' "historicity" is constituted by . . . philosophy's use of the ruses of literature, feint, and the fiction of the evil genius through which Cartesian discourse founds its veracity as a metaphysical discourse'. As my text will make clear, I disagree with some of the aspects of Judovitz' argument.
17 See note 15, above.
18 In my work on Descartes' *Géométrie* I was fortunate to have the very valuable presence of Elzbieta Szymanska-Swiatek as my research assistant, funded by the Social Sciences and Humanities Research Council of Canada.
19 AT vi. 372.
20 AT vi. 382 and 414.
21 AT vi. 372.
22 AT vi. 417.
23 AT vi. 422.
24 AT vi. 423.
25 AT vi. 444.
26 AT vi. 447.
27 AT vi. 453–4.
28 My interpretation at this point follows that of Michael Mahoney, 'The beginnings of algebraic thought in the seventeenth century', in Stephen Gaukroger, ed., *Descartes: philosophy, mathematics and physics* (Brighton, 1980) 141–55, 146. He writes: '. . . the intuitive aspects of geometry diminish. According to Descartes, every equation $x^n + a^1x^{n-1} + \ldots + an = 0$ is a complex relation that consists of the simpler relations $x - a = 0$, $x - b =$,. . . ., $x - s = 0$. Each quantity a, b, c, . . . s is a root of the original equation, that is, each may be substituted for x without disturbing the equality. From experience, however, Descartes knows that quite often not all roots of a given equation can be found numerically or geometrically. For example, if one tries to factor the equation $x^3 - 1 = 0$ into the form $(x - a)(x - b)(x - c) = 0$ one finds $a = 1$, of course, but no values at first for b and c. Nevertheless such values must exist or at least be imagined in order for the structural analysis of the equation to retain its generality. Hence Descartes summons his 'imaginary' roots into existence.'
29 AT vi. 444–5.

30 AT vi. 469.
31 AT x. 455–5.
32 In the *Regulae*, Rule 16, Descartes' use is to 'employ the letters *a*, *b*, *c*, etc. to express magnitudes already known, and *A*, *B*, *C*, etc. for ones that are unknown' (AT x. 455). In the *Géometrie* the capital letters are replaced by *x*, *y*, *z*, etc.
33 Consider the simple example which Descartes uses in Rule 16 of the *Regulae*, that of finding the length of the hypotenuse (AC) in a right-angled triangle the length of whose other two sides (AB and BC) are 9 and 12 units. We could make this a matter of the senses and through measurement obtain the result; but this would give no more than a specific result in a particular situation, hence would not be science. Or we could take the square of 9, add it to the square of 12, find the square root of their sum (225) and come up with the correct answer (15), now arithmetically determined. In this case, we have given names to the lines (AB, BC, and AC), have abstracted from these names by replacing them with numbers, and used these numbers in the arithmetical manipulations of multiplication, addition, and root-extraction. But we are still dealing with specific numbers (hence with a specific triangle), and the number from which we extracted the root (225) does not reveal that it is composed of two magnitudes in a specific relation. But if we abstract from lines, names, and numbers (so that AB = 9 = a, BC = 12 = b, and AC = ? = c) the solution can be written as $c = \sqrt{a^2 + b^2}$. This is not only a truly general statement; it is also one which keeps the various elements distinct.
34 In the example of footnote 33 above, the unknown quantity is *c*. In this connection I should point out that I believe Schuster to be wrong when he argues that Descartes abandons the *Regulae* precisely at the point where he realizes that 'imaginative representation' (i.e. use of corporeal imagination) 'or geometrical presentation at all' cannot 'ground' 'mathematical truths' and that therefore Descartes moves to 'a more abstract-relational view of the grounds of mathematical truth'. I believe the latter view is already that of the *Regulae* and that the example I have just used illustrates precisely this point. See John A. Schuster, 'Whatever Should We Do with Cartesian Method? – Reclaiming Descartes for the History of Science' in Stephen Voss, ed. *Essays on the Philosophy and Science of René Descartes* (Oxford, 1993, 219).
35 When Emily Grosholz writes that, for Descartes, (a) 'algebraic expressions and manipulations had to be referred back to the geometric diagram, in order to avoid mistakes which arise in the manipulation of empty symbols', and that (b) 'the geometric diagram is then the source of discovery', this (a) restricts the limits of analytic geometry in a way which Descartes resisted (there is more to analytic geometry than what can be referred to geometric diagrams), and (b) that 'discovery' is then only about the relation between the possible and the actual, not about the possible (that is, the geometrical) as such. See Emily R. Grosholz, 'Descartes' unification of algebra and geometry' in Gaukroger, ed., op. cit. The first quotation (in which Grosholz quotes T. LeNoir) is from p. 168; the second is from p. 160.
36 It is in terms of the generality which characterises his system, that Descartes dismisses the charge of being a follower (or even a copier) of François Viète. To Mersenne, Descartes writes 'if you compare what I wrote . . . concerning the number of roots in each equation with what Viète has written on this topic . . . you will see that I determine this question for all equations in general. He, by contrast, gives merely some particular examples. . . . Thus I began where he left off'. (AT i. 479).
37 Here, I enter terrain in which a number of critics have worked during the last decade. I have in mind Emily Grosholz, *Cartesian Method and the Problem of Reduction* (Oxford, 1991), chs. 3 and 4; Stephen Gaukroger, 'The nature of

abstract reasoning: philosophical aspects of Descartes' work in algebra' in John Cottingham, ed., *The Cambridge Companion to Descartes* (Cambridge, 1992), 91–114; David Rapport Lachterman, *The Ethics of Geometry: a genealogy of modernity* (London, 1989), passim; Amélie Oksenberg Rorty, 'Descartes on thinking with the body', in *The Cambridge Companion to Descartes*, op. cit., 371–92; Véronique Fóti, 'The Cartesian imagination', *Philosophy and Phenomenological Research* vol. 46 (1986), 631–42; and Edward van Leeuwen, *Descartes' Regulae: De eenheid van heuristische wetenschap en zelfbewustzijn* (Amsterdam, 1986), 204–11.

38 This mutual 'relativising' or 'limiting' has been discussed by various recent commentators. See, e.g., David Lachterman, *The Ethics of Geometry*, 173–4, and 196.

39 The disregard of this priority in classical geometry was, says Descartes, one of the causes of its incapability of developing beyond certain boundaries. It 'displayed many geometrical truths before my very eyes ... and there is nothing more futile than devoting our energies to those superficial proofs which are discovered more through chance than method and which have more to do with our eyes and [corporeal] imagination than our intellect; for the outcome of this is that, in a way, we get out of the habit of using our reason'. (AT x. 375).

40 In this connection, Amélie Oksenberg Rorty writes about the discussion of the piece of wax in the Second Meditation that 'Descartes is primarily concerned to show that the general ideas of extension and of its essential properties are intellectual ideas, independent of the [corporeal] imagination ... Because imagination-ideas about physical objects logically presuppose intellectual ideas, the general ideas of extension are best analyzed by an investigation of intellectual ideas'. See her 'Descartes on thinking with the body,' op. cit., 371–92, 376–77. In the last of these sentences – given that she writes about analysis of 'the general ideas of extension' – replacing the phrase 'are best' with 'can only be' would, I think, do greater justice to Descartes' position.

41 In 'The Cartesian Imagination', op. cit., Véronique Fóti alludes to both the mediating and limiting roles of corporeal imagination when she writes that 'the imagination ... can be at the behest of the intellect and serve as both the medium and the limit marker of representation' (636). See here also the excellent discussion of corporeal imagination as 'mediator' in E. van Leeuwen, *Descartes' Regulae*, op. cit., especially 204–11.

42 AT vii. 385.

43 Descartes is acutely aware of this limiting role of corporeal imagination and sensation. See Rule 14: AT x. 440–41, 444, 455, as well as his statement at AT x. 449: 'Although these three dimensions [of length, breadth and depth] have a real basis at any rate in every extended thing simply qua extended, we are no more concerned with them here than with countless others which are either intellectual fictions – *quam alias infinitas, quae vel fingunter ab intellectu* – or have some other basis in things.'

44 AT x. 457–8.

45 The mature Descartes, if not fully conscious of this fact, at least goes beyond the link between imagination and science to that between poetry and minds which are 'strong' and 'refined'. His last mention of poetry and imagination occurs less than a year before his death, in the correspondence with Elizabeth of Bohemia (AT v. 281). It links mind (imagination) and body (animal spirits) in a passage which lauds poetry as the product of 'a mind which is stronger and more refined than usual' and finds itself under extreme pressure – such as the minds of Socrates and Elizabeth: of the former while in prison awaiting death, of the latter while sick and in anguish about the beheading of her uncle, Charles I of England.

21 Descartes' theory of visual spatial perception

Celia Wolf-Devine

Descartes regarded his theory of vision as important to his project of replacing theories of a broadly Aristotelian sort with his own mechanistic natural philosophy. It is, for example, in his *Dioptrique* rather than in his more narrowly philosophical writings that he claims to have laid to rest the 'intentional species' that had played such an important role in scholastic epistemology.[1] Developing a satisfactory account of vision was necessary, he believed, because 'the principal reason which moved philosophers to posit real accidents was that they thought the perceptions of the senses could not be explained without them'.[2] And vision, of all the senses, is, on the face of it, the least amenable to mechanistic explanation; objects do not touch our eyes, and sight had long been regarded as the most spiritual of the senses. For vision was thought to have the highest power to abstract forms from matter, by contrast with touch which had the lowest power to do so; the eye can see a colour without physically becoming coloured, whereas the hand literally becomes warm when feeling a warm object. Thus, if he could explain vision without employing traditional Aristotelian concepts such as forms, species, or real qualities, providing a mechanistic account of the other senses would presumably pose no difficulties.[3]

His attempt to develop an alternative account of vision couched in mechanistic terms was, in his own eyes, successful.[4] His theory is, however, imperfectly mechanistic; he often supplements his mechanism by postulating various mental acts, such as directing attention out from one's hands or eyes, or making judgments to correct for perspective distortions of size and shape. As a metaphysical dualist, of course, he believes himself entitled to do this, but serious difficulties arise if one tries to integrate the components of his theory into a coherent whole.

In section 1, I briefly describe the formation of the retinal image, the anatomy of the visual system, and the way in which the retinal image is transmitted into the cerebral cavities and, ultimately, to the pineal gland. In Part 2, I show how mechanistic explanations of our perceptual abilities exist side by side with an inner homunculus in his explanation of visual spatial perception, citing some representative texts. In Part 3, I point out some of the difficulties that arise as a result of this juxtaposition of different models. In Part 4, I offer some concluding thoughts about why Descartes became entangled in the particular difficulties he did, and how he might extricate himself from them; I suggest that resolving the sorts of problems Descartes was struggling with will necessitate, among other things, getting clearer about just what it is that we are looking for in seeking an explanation of our perceptual abilities.[5]

1

Like Aristotle, Descartes holds that our perception of light and colour results from a kind of action of the intervening medium (rather than something travelling from the object to the eye), but while Aristotle understands this action in terms of qualitative modifications of the medium, Descartes provides a mechanistic account of it. He explains light in terms of the pressure that luminous bodies exert upon the air particles, which in turn press upon the eye. Descartes' theory of colour is not without difficulties and obscurities,[6] but the key idea is that colour is a function of the movement of the little balls that represent light (his third model for light). More specifically, it is a function of the ratio between the speed at which they spin around their own centres and their forward motion.[7] Objects impart various sorts of spinning motions to the balls when they are reflected from them and this is why they appear to have the colours they do.

The light rays reflected from objects are brought to a focus on the retina by the lens. The formation of the retinal image is depicted in this illustration of an experiment which Descartes himself performed (Figure 21.1). He instructs the reader to take the eye of a cow or a newly dead man and remove the back surface or retina, leaving the rest of the eye as undisturbed as possible, to place a piece of opaque paper or egg shell behind it, and in a dark room to put the eye in the hole of a specially made window that looks out on a brightly illuminated scene so that light enters only through the eye. The reader will then, he says, see a picture ('*peinture*') appear on the paper that represents all the objects in perspective. Light travels from objects V, X, and Y, the light from each point on the object being reunited at a corresponding point on the opaque sheet of paper. If the light being reflected by object X is yellow, then as it shines through the paper it will cause us to see yellow at point S; if V is reflecting blue light, we will see blue at point R, and so also for Y (say it is red), and T. What appears on the paper will have the same colours in the same order as V, X, and Y, thus resembling them.

This little picture, however, has certain imperfections: it is clear only in the middle, 'its parts are reversed, that is to say in a position completely contrary to that of the objects; and . . . they [the parts] are elongated and shortened some more, some less, because of the differing distance and situation of the things which they represent, in the same way as in a perspective painting'.[8] A small, close object occupies as much space as a

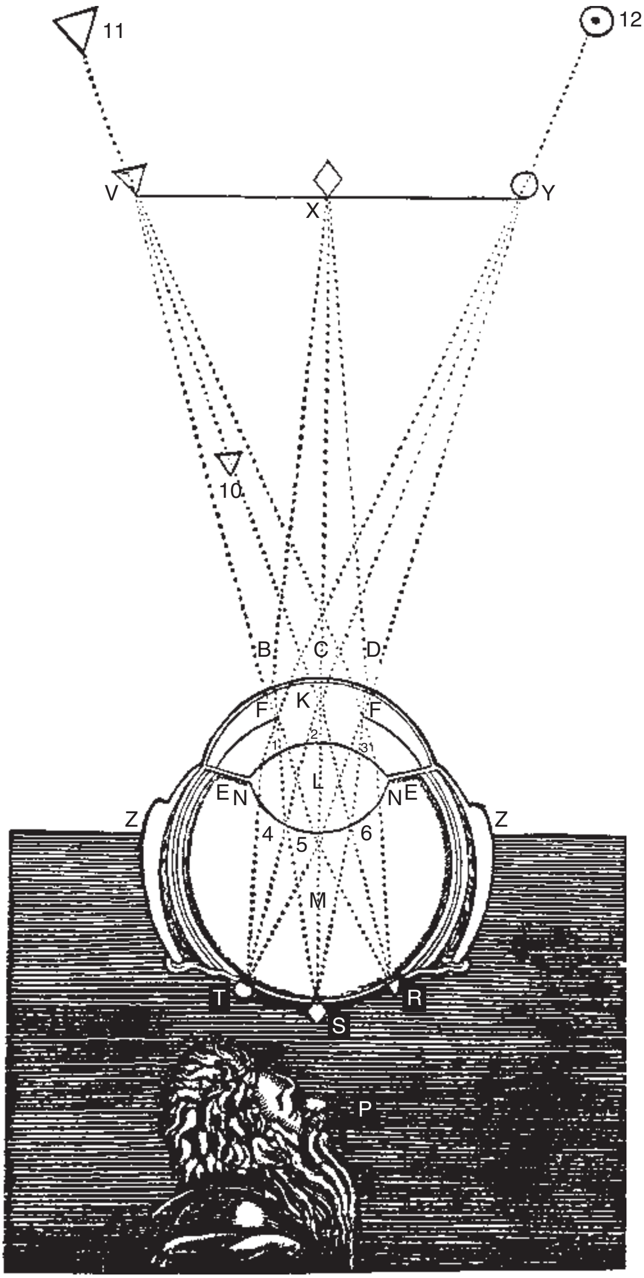

Figure 21.1

larger, more distant one, and a straight line, VXY, is represented by a curved line, RST, due to the curvature of the eye.

This explanation of the retinal image and its manner of formation is dramatic and easily visualisable. However, an unwary reader could easily be misled into supposing that in vision the soul, like the man in the dark room, somehow gazes upon the pictures painted on the bottom of the eye – a view that would obviously lead to a vicious regress, since another eye would be needed with which to see the picture. For, although the light rays impart various sorts of motions to the nerves in the retina, no 'picture' appears until the causal chain is broken, the retina replaced by an opaque white body, and another eye introduced.

Descartes is aware of the dangers of this sort of inner homunculus gazing at the retinal image. He insists that 'the soul has no need to contemplate any images which are similar to the things it senses',[9] and tries to head off the threat of an infinite regress by noting that

> while this picture [*peinture*], in passing thus into the inside of our head, always retains some resemblance to the objects from which it proceeds, we must nonetheless not be persuaded that it is by means of this resemblance that it enables us to sense them, as if there were yet other eyes within our brain with which we could perceive it.[10]

But even though the soul has no *need* to contemplate images similar to the things it senses, the retinal image clearly *does* bear a resemblance to the objects depicted in it, and it retains this resemblance as it is transmitted inward to the seat of the soul at the pineal gland. Descartes is in a better position to explain what happens beyond the retina than his predecessors were because his mechanisation of light and colour enables him to treat the retinal image as a pattern of motions which can be transmitted mechanically along the nerves. The images from the two eyes are transported into the cerebral cavities (Figure 21.2), and from there to the pineal gland where they are merged to form one image. This is, he believes, necessary in order to account for the fact that we see one object with two eyes. Descartes provides no diagram of this last stage in the perceptual process,[11] and his characterisation of it in the *Dioptrique* differs somewhat from that in *L'Homme*, where he spells out the role of the animal spirits in the formation of the pineal image, but these differences need not concern us here.[12]

Essentially, then, what Descartes has done is to provide a sort of mechanised Aristotelianism in which the 'figure' rather than the 'form' of the object is conveyed to the soul at the pineal gland. A pattern of light projected onto the retina is converted into a pattern of motions at the surface of the pineal gland. The visual system, thus, functions rather like an Opticon – a device, used by blind people, which is moved along a line of print. It converts the pattern made by letters on a page into a pattern of

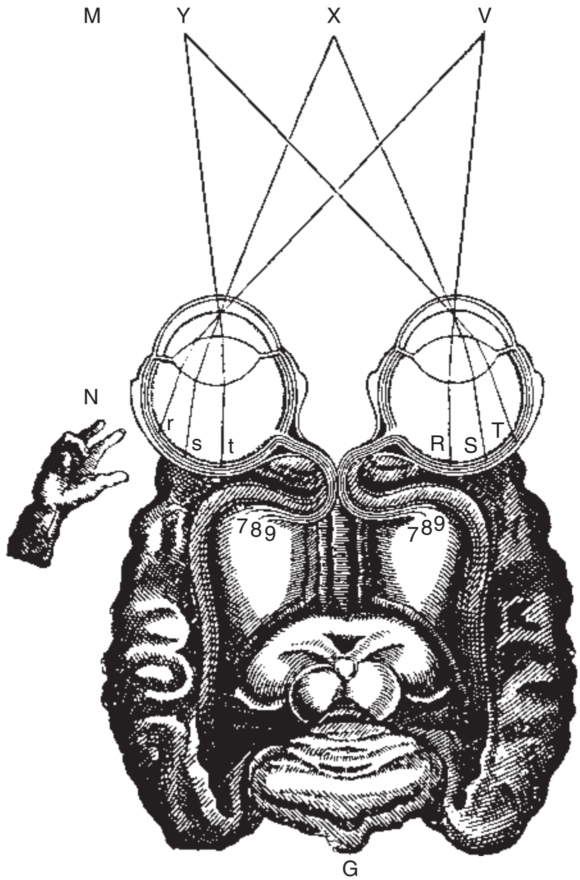

Figure 21.2

vibrations that can be felt on the tip of a finger. The pattern of motions at the surface of the pineal gland, then, acts immediately upon our soul (*agissant immediatement contre notre âme*)[13] in a way instituted by Nature to make us have certain sensations.

2

Light and colour perception would seem, on the face of it, to be adequately explained by the mechanisms described above. Although the motions that compose the pineal image bear no resemblance to light or colour as we experience them, they make us have sensations of light and colour because of the way God joined our mind with our body (just as the motions in the nerves coming from the ears cause us to hear sounds). But, even leaving aside the problem of colour constancy (which Descartes does not seem to be aware of),[14] things are not quite so simple. We perceive colours (unlike, say, odours) as spread out in space, and thus colour perception is interwoven with our perception of size and shape, which are in turn connected (on Descartes' view) with our perception of situation and distance. And since, according to Descartes, the pattern of motions at the pineal gland is structurally isomorphic with the retinal image (which is roughly two-dimensional, inverted, reversed, and subject to perspective distortions of size and shape), an explanation must be given of how we are able to perceive correctly by sight the situation, distance, size and shape of objects.[15]

Supplementary mechanisms, then, must be postulated over and above the point-to-point projection of the retinal image to the pineal gland, and the ones Descartes provides form a rather heterogeneous and ill-assorted group. Some of them do not seem to require any sort of activity by the soul. A certain change in the position or motion of the parts of our brain simply causes a certain perception as a result of the 'institution of Nature' (i.e. the way God joined our souls and bodies together). But others involve a kind of inner homunculus; the soul *does* things like directing attention out from various body parts to determine the situation of objects, or correcting for perspective distortions in the retinal image on the basis of its knowledge or opinion about their distance and situation.

The clearest example of Descartes' reliance on a mechanistic model is in *L'Homme*, where he suggests that the degree to which the pineal gland leans toward or away from the centre of the brain is one of the things by which we are able to know the distance of objects.[16] And in the *Dioptrique*, he supposes that when we change the shape of our eye to bring a near object into focus, we 'change also a certain part of our brain, in a way which is instituted by Nature to make our soul perceive this distance (*faire apperçevoir à notre âme cette distance*)'. This happens ordinarily without our thinking about it, he says, just as we grasp an object which is in our hand without having to think about the movements our fingers make.[17]

Simple situation perception (perception of the direction in which an object lies relative to our body) is likewise explained mechanistically. Our perception of this builds upon our awareness of where the various parts of our body are in relation to each other (itself a result of the institution of Nature). Our awareness of the direction in which our eye or head is turned enables us to determine where the object is located relative to our body, just as a blind man touching an object with a stick can tell what direction it lies in because he knows the direction in which his hand is turned.

But in the more complicated case of determining the relative position of several objects seen with one eye fixation, Descartes begins to drift in the direction of an inner homunculus, developing an analogy between a blind man with crossed sticks who is able to feel an object to the right with his left hand and one to the left with his right hand and a person who sees objects in their true situation 'although the picture which they print in the eye has a wholly contrary situation'.[18] The blind man is not confused by the crossed sticks because he can direct his attention out from his hands along straight lines to tell where the objects are (even though ordinarily he may not do this consciously). Descartes does not explicitly say that we can direct our attention out from various retinal points, but if one takes the analogy seriously it would seem to follow that we at least *can* do this.

The homunculus model is most prominent in his discussions of shape and size perception and in his account of monocular distance perception.

In *L'Homme*, Descartes says that shape perception can be explained simply by the fact that the light rays trace on the retina a figure which corresponds exactly to that of the object.[19] But in the *Dioptrique* he says:

> Figure is judged by the knowledge or opinion we have of the situation of the different parts of the object, and not by the resemblance of the pictures in the eye: for these pictures usually contain only ovals and rhombuses when they make us see circles and squares.[20]

Size perception likewise involves judgment according to Descartes:

> Their size is estimated by the knowledge or opinion we have of their distance, compared with the size of the images which they imprint on the bottom of the eye; and not absolutely by the size of these images, as is obvious enough from the fact that when they [the images] are a hundred times larger when the objects are very close to us, they do not, for all that, make us see them as 100 times larger, but as nearly the same size, at least if we are not deceived about their distance.[21]

Descartes' account of distance perception involves the same analogy between vision and a blind man feeling objects with sticks that he used for situation perception. (This is, of course, more than just an analogy since Descartes' theory of vision essentially treats vision as a special form of touch.) In the case of binocular distance perception, he says that we 'know' distance (and here the French verb is *connaître*, which has the meaning of 'to be acquainted with' – the same verb he uses in the situation section)

> by the relation which the two eyes have to each other. For as our blind man, holding two sticks AE, CE, whose length I suppose him not to know, and knowing [*savoir*] only the distance between his two hands A and C, and the size of the angles ACE and CAE, can from that, as though by a natural geometry, know [*connaître*] where E is [Figure 21.3]; thus when our two eyes RST and rst are turned towards X, the length of the line Ss and size of the two angles XSs and XsS make us know [*connaître*] where the point X is [Figure 21.2].[22]

There are three interesting things about this passage. The first is his use of the verbs *savoir* and *connaître*. The verb *savoir* (connoting an intellectual

Figure 21.3

kind of knowledge) is used to describe the blind man's knowledge of the distance between his hands and the angles made by the sticks, while *connaître* (meaning 'to be acquainted with') is used to describe his knowledge of where the point E is, as though he is trying through this use of the different verbs to arrive at the sort of directness and immediacy associated with the verb *connaître*, starting from intellectual and perhaps implicitly mathematical knowledge.[23] Second, Descartes refers to natural geometry only in his discussion of the blind man, whereas in the case of vision, he says that the length of the line and the size of the angles 'make us know' (*connaître*) where the point E is. Third, Descartes says that we know where the point E is 'as though by a natural geometry', and does not claim that we actually *use* geometry – a claim that would cause all sorts of problems even in the more plausible blind man case. It may be plausible to assert that the blind man knows the direction his hands are turned, but surely one would hesitate, for example, to say that he knows his hands are 18 inches apart and that the base angles formed by the sticks are 55°. This would obviously be a hopeless over-intellectualisation of perception.

In the case of monocular distance perception, however, Descartes relies more explicitly on an act of judgment. A blind person with only one stick whose length he does not know, could not tell how far away an object was. So a person with only one eye must look at the object from point S and then move to look at it with the same eye from point s (Figure 21.2).

> This will suffice to make the size of the line Ss and of the two angles XSs and XsS found together in our imagination, and to make us notice the distance of point X; and this by an act of thought which, being only a completely simple imagination, nonetheless includes within itself a reasoning similar to that which surveyors use when they measure inaccessible places by means of two different observation points.[24]

Here, at last, we have an explicit reference to an act of thought which includes reasoning. However, its status is quite unclear. It is an act of thought essentially involving the imagination, since the imagination retains the information necessary for determining the distance of the object – namely, the length of the line and the size of the angles. It is a simple act of thought, presumably because we discover no parts in it; it occurs in such a way that we are not aware of making any inferences or doing any reasoning. Yet it includes some sort of reasoning, and it must be the soul that does this, since only mental substances can engage in reasoning.

3

The homunculus model generates some serious difficulties for Descartes. For when he employs it, he speaks of the soul making judgments of various sorts – for example, correcting for perspective distortions of size and shape. Such judgments are anomalous for two reasons. First, it is clear that the retinal image and/or its pineal correlate have a privileged status in vision, but very unclear just what that status is. Descartes clearly rejects the view that the soul somehow gazes at the retinal image on the grounds that it would require the soul to have eyes. Yet his account of size perception, for example, requires that we have access to the retinal image in *some* sense. In what sense do we and in what sense do we not have access to it? Second, given Descartes' equation of mind with consciousness, any mental act must be something we are aware of or at least *can* be aware of, But it seems (prima facie at least) impossible for us to be conscious of many of the sorts of activities Descartes attributes to the mind when using the homunculus model. The blind man *could* consciously think about the position of his hands and direct his attention out along the sticks (even though he normally does not do so), but directing our attention out from various points on our retinae does not seem to be something we can do consciously at all.

Furthermore, how are his two different sorts of explanations to be fitted together? While Descartes may be entitled to use two different models, he appears to be unaware that he is doing so, and therefore fails to address some important questions. How are we to tell when we should employ one model rather than the other? Are some types of perceptual abilities wholly explainable by only one of the models or are both of them operative in all perception? If both are operative, how can the soul be, at the same time, wholly passive (as it is on the mechanical model) and actively involved in reasoning and judging (as it is on the homunculus model)? Is there any reason, in principle, why we must retain the homunculus model, or could it be dispensed with as our mechanistic explanations become increasingly complex and sophisticated?

Consider, for example, the case of monocular distance perception discussed above. Why does he find it necessary to postulate reasoning here?

There are several possible reasons. The most distinctive thing about this case is that it necessarily involves memory, at least the sort of short-term memory involved in the imagination retaining information between the first and second eye fixations. This, however, seems to be merely the sort of corporeal memory we share with the animals and not anything that would make it necessary to postulate an act of reasoning.

Another possible reason is that we find with both binocular and monocular distance perception a certain sort of irreducible complexity not found with our perception of situation. Given Descartes' explanation of vision by means of a point-by-point projection of the retinal image to the pineal gland, one fixation of one eye just cannot be enough – either two eyes or two eye fixations are required. Thus, it would seem that the mind must somehow be involved in the comparing and combining of the different inputs. This may well be what moves Descartes to speak of reasoning here, although if it is, it is not clear that the necessity of combining several inputs requires us to postulate any reasoning process or involvement of the mind. After all, several inputs are involved in even the simplest of perceptions – such as my seeing a blue object to my right, which involves at minimum the different motions that cause me to perceive blue, plus the changes in the brain that enable me to tell which direction my eyes and head are turned. There seems, thus, in principle, no reason why a mechanistic explanation could not accommodate any number of inputs simply by hypothesising that when all these changes occur in the brain simultaneously, they cause us to have certain perceptions, without reference to the mind engaging in any reasoning process.

The only other possible reason for postulating an act of reasoning here is that in these two cases the inputs to be combined are at least implicitly mathematical – the length of lines and the size of angles – so it would seem that the powers of reason would be required. An animal would, presumably, be quite incapable of perceiving distance in this way. Had Descartes provided any account of animals' visual spatial perception, it would have been very helpful for our understanding of human distance perception, but the part of the *Principia* that was to deal with plants and animals was never completed.

Finally, then, how could Descartes' explain the perceptual capacities of animals? To take distance as an example, if judgment or reasoning is necessarily involved in distance perception, it would follow that animals could not perceive distance. And if the standard interpretation of Descartes' view of animals is correct[25] – namely, that they lack any sort of consciousness at all – then we cannot explain their perceptual abilities by the way God joined the motions in their brains with sensations either.[26] Yet some animals at least are clearly able to tell by sight how far away things are. Although we do not know how Descartes would have explained this fact, there are indications that he saw animal perception operating in much the same way that human perception does, at least for some range of perceptual abilities, since the drawings he uses in the *Dioptrique* were drawn from a sheep's brain.[27] As he explains in a letter to Mersenne in 1637,

> the figure of the brain which I put in the *Dioptrique* is drawn from that of a sheep, of which I know that the ventricles and other interior parts are much larger because of all of the mass of the brain, than in that of a man; but I judged it even more appropriate for this subject to make it possible to see that of which I was speaking, which is common to beasts and men; for I did not suppose anything new or controversial in anatomy.[28]

Descartes employs the drawing in the *Dioptrique* while talking about the physiology of the visual system, and therefore it follows that he believes that the basic physiological mechanisms he describes there are 'common to beasts and men'. How, then, does a sheep perceive the distance of objects? Even those who contend that Descartes does not deny consciousness to animals,[29] or that Descartes need not have denied consciousness to animals and had no good reason to do so,[30] still do not contend that Descartes believes animals to be capable of making judgments of the sort he ascribes to the human soul in his discussion of spatial perception. So how *do* animals perceive the spatial properties of objects? These problems did not arise in the same way in the Aristotelian framework, since the sensitive soul, which was common to animals and human beings, performed many of the functions which Descartes attributes to the mind.

On the other hand, if we suppose that a wholly mechanistic explanation *could* be given for animals' visual spatial perception,[31] then it would seem unnecessary to postulate judgment in the human case. Descartes, thus, seems forced to choose between either intellectualising animal perception (which is, of course, out of the question), or completely mechanising human perception (or at least those perceptual capacities we share with beasts).

It might seem, in light of what has been said so far about his desire to replace the Aristotelian account of sense perception with one more compatible with the new mechanistic science, that Descartes would unambiguously welcome increasingly sophisticated mechanistic accounts, in the hope that these would eventually obviate the necessity of assigning any role to judgment in perception.[32] I am inclined, however, to think that Descartes might be hesitant to eliminate completely the element of judgment from his account of human perception. Just how far he wants to go in mechanising the various processes that occur in the body–soul composite is not entirely clear. Several other essays in this volume discuss this question (especially those by John Sutton and Dennis Des Chene), so I limit myself to a few comments bearing on sense perception.

Certainly, Descartes is not *required* to eliminate the element of judgment from perception.[33] He is after all a dualist and not a materialist. True, he wants to eliminate Aristotelian forms, real qualities and species from the world, and having eliminated them from the world, he cannot postulate them in explaining the processes that occur within the perceiver's body; they are not out there to act on our senses. He also wants to eliminate the Aristotelian nutritive and sensitive souls,[34] but the existence of an immaterial soul that distinguishes humans from beasts is something Descartes is strongly committed to. Certain human capacities can only be explained by reference to the rational soul – language use, for example.[35]

Not only is Descartes not required to eliminate the element of judgment in perception, but he might regard it as ineliminable in principle, since perception is a cognitive faculty (unlike, say, digestion or respiration). He says at the start of Discours IV of the *Dioptrique* 'it is the soul that senses and not the body,' citing as evidence the fact that when the soul is distracted by ecstasy or contemplation the body remains without sensation.[36] He would not say that it is the soul that digests our food or causes our hearts to beat. Since the only soul we have is the rational soul, our sensory capacities would seem to be interwoven with and pervaded by reason. The perceptual capacities of the soul–body composite, then, being the powers or capacities of a rational being, at least *may* diverge in some important ways from the perceptual capacities of animals. Just where the divergences occur is, I believe, something Descartes had not worked out to his satisfaction,[37] although there are intriguing hints scattered about in his works.

4

Why did Descartes get entangled in the sort of difficulties he did, and how might he extricate himself from them?

One reason for his difficulties, I think, is that he retained certain features of the Aristotelian way of thinking about perception, which, when coupled with his mechanism, led him into erroneous suppositions about the role of the retinal image in vision. He was, as Wittgenstein might say, held captive by a picture. Descartes really knew very little about the structure and function of the visual system (his ideas about the animal spirits and the pineal gland, for example, were almost pure science fiction[38]). For this reason philosophical assumptions played a large role in shaping his physiological hypotheses, and his own philosophical training had been largely in the Aristotelian tradition.

Like Aristotle, Descartes believes that some sort of unification of the input from the senses must occur on a physiological level in order to explain the unity and integration of our sensory consciousness. And while Aristotle sees sensation as a process in which the sense receives the form of the object and conveys it inward to the seat of the common sense, Descartes thinks in a similar way, but replaces 'form' with 'figure':

> It is necessary to beware of assuming that in order to sense, the mind needs to perceive certain images transmitted by the objects to the brain, as our philosophers commonly suppose; or at least the nature of these images must be conceived quite otherwise than as they do. For inasmuch as they [the philosophers] did not consider anything about these images except that they must resemble the objects they represent, it is impossible for them to show us how they can be formed by these objects, received by the sense organs, and transmitted by the nerves to the brain.[39]

Descartes' theory, then, fills in this gap, showing how the retinal image is formed and projected to the cerebral cavities and, ultimately, to the surface of the pineal gland, thus producing a resembling image of sorts. The pattern of motions at the surface of the pineal gland is not an image in the sense of being something we can look at, but it is structurally isomorphic with the retinal image. Each retinal point is represented in the pineal gland image – or rather as many retinal points are represented as the number of the optic nerves – and spatial relationships between them are preserved. It thus bears a resemblance to the object seen, but the resemblance is an *imperfect* one, due to perspective distortions of size and shape, and thus an explanation must be given of how the imperfections of the retinal image are corrected for. This, in turn, entangles him in the thorny problems discussed above concerning our access to the retinal or pineal images and the nature of the corrective judgments involved. Paradoxically, Aristotle, knowing less about vision, did not fall into this sort of difficulty, since he did not try to specify what physical processes were occurring when the sense faculty was taking on the form of the object.

Aristotle took the heart to be the seat of the common sense, while Descartes took it to be the pineal gland, but the underlying rationale given for believing that some sort of unification of the input from the senses had to occur on a physiological level was surprisingly similar.[40] Subsequent research on the visual system, however, has discovered that the retinal images are not in fact merged; they are projected to several different areas of the brain and are subject to topological distortion. The eyes are in constant rapid motion so that the image projected on the retina changes constantly while our visual field remains stable. So while the retinal image still retains a central role in vision, that role must be quite unlike that envisioned by Descartes, and the unity of our visual field cannot be read off the physiology of the visual system in any simple way.[41]

In light of all this, then, how might we try to resolve Descartes' problems about visual spatial perception? If we remain within the basic framework he set out – his dualistic metaphysics and his account of the structure and function of the visual system (described in section 1 above) – then some explanation must, indeed, be given for why we do not perceive things as they are represented in the retinal image. His successors tried several different ways of resolving this problem, but none of them appears to be entirely satisfactory.

One way of attempting to solve the problem was to accept Descartes' view that the mind or soul makes some sort of corrective judgments, and try to clarify their nature and explain why it is that we are not conscious of making them. Perhaps the mind does really make judgments, but we do not notice that we are doing so because these judgments have become so quick and habitual.[42] But this is subject to serious objections. For one thing, there is the problem of animal perception discussed above. But even in the human case, some of the judgments Descartes postulates involve things of which we cannot be aware. We thus could never have made such judgments consciously in the first place, so they could not have become habitual.

Or we could drop the notion of judgment and replace it with mere association of ideas. The perception of certain ideas, then, simply causes our minds to perceive also other ideas that have been experienced in close conjunction with them. A thorough examination of this line of thought cannot be undertaken here, although, on the face of it at least, this sort of explanation seems not to explain, but merely to state that as a matter of brute fact certain ideas tend to be aroused by other ideas commonly associated with them. Some reason should at least be given for why certain ideas bring others to mind (memory traces in the brain?, the action of God?, etc.).[43]

A third and more radical way to resolve the problems with the special status of the retinal image (and its pineal correlate) and the nature of the perceptual judgments involved in visual spatial perception is the hypertheologising route chosen by Malebranche. Realizing the enormous complexity of the judgments involved in correctly perceiving the size, shape, motion and distance of objects (he calls these 'natural judgments'), and noting the speed with which such judgments occur, Malebranche concludes that such judgments are performed not by the soul but by God, who excites them in us on the occasion of certain changes in our nerves and brains. God, he says,

> fashions them in and for us in such a way that we could form them ourselves if we knew optics and geometry as God does, if we knew everything that occurs in our eyes and our brain, and if our soul could act on its own and cause its own sensations. [He] always acts in consequence of the same laws, always according to the rules of geometry and optics, always dependently upon the knowledge of what takes place in our eyes compared with the situation and motion of our bodies, always in consequence of an infinity of instantaneous inferences which tend to preserve our life and which vary with each movement of our eyes.[44]

Natural judgments thus appear to us to be mere sensations, but in fact they can be considered in relation to God as a kind of judgment.

A fourth possibility is eliminating the homunculus and becoming more consistently mechanistic than Descartes himself was. We would then limit ourselves to describing the changes that occur in our nerves and brain when we perceive certain things visually. If these may be of any degree of complexity, then one could just say that whenever a certain complex set of changes in the nervous system and brain occurs, we have a perception of the situation, distance, size, and shape of objects – all this as a result of the institution of Nature.

Both the hyper-theologising route or the mechanistic route threaten to make God responsible for our errors – either directly in the case of Malebranche's solution, or indirectly in the mechanistic case, since the institution of Nature is God's doing. This may be one reason why Descartes did not choose either route.

Finally, we could cut the Gordian Knot and say that because the eye does not function like a camera, the retinal images are not merged in the way Descartes thought they were, and Descartes' hypotheses about the animal spirits and the pineal gland were incorrect; there is therefore no reason to suppose that, in the absence of corrective judgments, we would see things as they are represented in the retinal image. Many of Descartes' problems were, then, pseudo-problems. On the whole, this seems the best route to take.

This, however, leads to one last question. What is it that we are looking for, in seeking an explanation of our ability to visually perceive the situation, distance, size and shape of objects? One can, of course, under laboratory conditions, discover that binocular disparity is important for depth perception by presenting slightly differing images to the two eyes and observing how this affects the subject's perception of the third dimension. One can determine which parts of the brain are involved in vision by monitoring electrical activity in certain regions and correlating this with the presentation of varying stimuli or with the subject's introspective reports. One can even artificially stimulate parts of the visual cortex and either observe the subject's behaviour or (in the case of human subjects) have the subject describe his or her visual experience.

But there is something unsatisfying about invoking these sorts of things as explanations of our visual capacities. This happens, and then that happens, . . . and then we see. There is an abrupt jump from some sort of complex description of the condition of our nerves and brain to our conscious experience. An explanation should, after all, make the phenomenon explained more intelligible.

What constitutes an explanation, and why, is one of the most difficult questions in philosophy. But, minimally, an explanation is called for when some phenomenon cannot readily be accounted for on the basis of a given background theory or world picture. And what counts as an explanation has something to do with the purposes of the person seeking it. Descartes thought he had a pretty clear handle on what the world was like and, on the basis of his hypotheses about the structure and function of the visual system, our capacity to perceive the situation, distance, size and shape of objects by sight, required further explanation. He also had a well articulated purpose in mind – namely, to develop a coherent philosophical system that would facilitate the development of mechanistic physics while leaving room for an immaterial soul so that the truths of the Catholic faith would not be compromised.

We, I think, are less clear than Descartes about our underlying picture of the world, and have become overloaded and confused by the mass of data we now have about the visual system. Consequently, we are less clear about why visual spatial perception is particularly problematic – if indeed it is. Moreover, the purposes with which philosophers and scientists enter discussion of these issues vary enormously and indeed are sometimes in open conflict. Neither belief in a mechanistic world picture nor a desire to protect traditional religious beliefs can be taken for granted in contemporary discussions, and few, if any current researchers are committed to both. It is no wonder then that we sometimes find ourselves unsure at what points explanations are needed and what would count as an adequate explanation.[45]

Notes

1 AT, vi. 85.
2 Sixth Replies, AT vii.:435.
3 He makes this point explicitly in the Sixth Replies: 'I have promised that I will explain these facts minutely with reference to each sense in my Physics. Not that I wish that any of my opinions should be taken on trust, but that I thought that those who have judged correctly in the matter of those accidents which I have already explained in the case of vision in my *Dioptrique* will easily guess what I am able to make good in the case of the others.' (AT vii. 435).
4 See, e.g., Sixth Replies, AT vii. 435; *Météors*, AT vi. 331; *Passions de l'Âme*, AT, xi. 337–38; *L'Homme*, AT xi. 153; *Principia*, IV art. 189, AT ixB. 310; author's letters to translator of *Principles*, AT ixB. 15; *Notae in programma*, AT viiiB. 359.
5 For a fuller discussion of Descartes' theory of vision, see my *Descartes on Seeing: Epistemology and Visual Perception* (Carbondale, 1993). In it I develop the contrast with the Aristotelean view in more depth, say a great deal more about light and colour, connect the *Dioptrique* account with the *Regulae*, and bring out the tensions and inconsistencies between the role he assigns to judgment in the optical writings on the one hand and his discussion of the levels of sense in the Sixth Replies. The present essay distills material from several chapters of the monograph bearing on visual spatial perception, especially ch. 4. It also amplifies the monograph at several points, especially at the end of Part 3 and in Part 4.
6 See *Descartes on Seeing*, ch 2, of for a discussion of these.
7 For example, when the spin greatly exceeds the forward motion they generate our sensations of red, or yellow if the spin is a bit less. If it is less than the forward motion we see blue, or green if it is much less.
8 *Dioptrique*, AT vi. 123–4.

9 *Dioptrique*, AT vi. 114.
10 *Dioptrique*, AT vi. 130. The referent of 'it' here is ambiguous. It could refer to either the picture or the resemblance.
11 The diagram appended to *L'Homme* was added after his death.
12 It might seem that the mind is purely passive in the *Dioptrique* because it is the motions transmitted by the nerves that cause our sensations (by the institution of nature), and that it is more active in *L'Homme* since it is the pattern traced by the departing animal spirits in the surface of the pineal gland that gives rise to our visual sensations. But the animal spirits are material in nature, and their outflowing would not seem therefore to be indicative of any sort of *mental* activity – such as directing one's attention, etc. The crucial determinant of the content of our visual experience in both cases is a pattern of motions that is structurally isomorphic with the retinal image.
13 AT vi. 130.
14 In fact, the colour we perceive objects to be is not merely a function of the light reaching us from them. Objects perceived under unusual lighting are often perceived to have their normal colours, and, as Land showed, one can see familiar objects as having their usual colours (albeit a bit washed out) when all the light reaching the eyes is in the yellow part of the spectrum. Thus a purely mechanistic explanation fails even here.
15 Descartes thinks of these as 'common sensibles' (in Aristotelean parlance), describing them almost exactly as Aristotle does the common sensibles – as not belonging to a single sense only, but being 'common to touch and vision and even in some manner to other senses'. AT xi. 159.
16 AT xi. 183.
17 AT vi. 137.
18 *Dioptrique*, AT vi. 135.
19 AT xi. 159.
20 AT vi. 140–41.
21 *Dioptrique*, AT vi. 140.
22 *Dioptrique*, AT vi. 137.
23 In the parallel passage in *L'Homme*, Descartes uses the two verbs in exactly the same way (AT xi. 160).
24 *Dioptrique*, AT vi. 138.
25 This view is not unchallenged. For example, see John Cottingham, 'A Brute to the Brutes?: Descartes' Treatment of Animals', *Philosophy* vol. 53 (1978), 179–93, and Daisie Radner and Michael Radner, *Animal Consciousness* (Buffalo, NY, 1989), chs. 1–4.
26 On this point, see also Margaret Wilson, 'Descartes on the perception of primary qualities', in Stephen Voss, ed., *Essays on the Philosophy and Science of Rene Descartes* (New York, 1993), 172.
27 Animals such as eagles or bats may, of course, have very different sorts of organs and thus different ways of perceiving distance. But Descartes at least thought that the visual apparatus of sheep was anatomically similar to ours, so I will discuss the problem for sheep.
28 AT i. 378.
29 See, for example, Cottingham, in 'A Brute to the Brutes?' where he cites passages in which Descartes attributes feelings like hope, fear, and joy to animals (AT iv. 574).
30 See, e.g., Radner and Radner, *Animal Consciousness*, especially chs. 2 and 3.
31 Perhaps along the lines suggested by MacKenzie, whose interesting rational reconstruction of the *Dioptrique* in 'Descartes on Sensory Representation', *Canadian Journal of Philosophy* vol. 16 (1990), 127–41, is more consistently mechanistic than Descartes himself.

32 I am indebted to John Sutton for his probing questions on this particular point, and wish to thank him for a number of other comments that were helpful to me in revising this manuscript.

33 Nor does there appear to be any clear trend toward eliminating judgment from perceptual explanation. In his discussion of the three levels of sense in the Sixth Replies, for example, Descartes actually increases rather than decreases the role of judgment in perception (although his concerns in that work, of course, are different from those in the optical writings).

34 It is very clear in *L'Homme*, for example, that although he describes the body as a machine, it is the Aristotelean nutritive and sensitive souls that he is out to eliminate, not the rational soul (see AT xi. 202).

35 AT vi. 57.

36 AT vi. 109.

37 The problem of trying to understand how sense and reason interface with each other was by no means a new one. Descartes' Medieval predecessors had struggled with it as well. Thus Aquinas, for example, distinguished between what he called the 'estimative sense' (in animals) and the 'cogitative sense or discursive power' (in humans) which perform many of the same functions, except that in the human case there is an interplay between reason and sense that enables them to perceive the advantages and dangers of things in a way that goes beyond instinct. The problem of how sense and reason are connected, however, arises in a different way for Descartes than it did for them, since he has eliminated the sensitive soul and the forms or species that had performed a kind of bridge function between the sense faculty and the intellect. See ch. 1 of *Descartes on Seeing* for an extended discussion of this point.

38 He virtually admits this in a letter to Mersenne in April 1640, when he says that three years before he had attended the autopsy of a woman and found himself unable even to recognize the pineal gland 'even though I looked very thoroughly, and knew well where it should be, being accustomed to find it without any difficulty in freshly killed animals'. The old professor performing the autopsy, he said, admitted that he had never been able to see it in any human body: AT iii. 49. The fact that he could not see it does not, of course, disprove its existence in human beings. Nor does the invisibility of the animal spirits show that hypothesising them was illegitimate (since Descartes constantly hypothesises various micro-mechanisms analogous to macroscopic ones), or that their behaviour (if they exist) would not be explainable mechanistically. But given how little actual knowledge Descartes had to go on, his physiological hypotheses were particularly strongly influenced by his philosophical presuppositions.

39 *Dioptrique*, AT vi. 112.

40 See *Descartes on Seeing*, 58–60 for a discussion of the reasons given by each.

41 See Maurice Pirenne, *Vision and the Eye*, 2nd edn. (London, 1967), 193–6.

42 Descartes himself suggests this view in his Sixth Replies (AT vii. 438). As I have argued in *Descartes on Seeing*, however, his account of perception in the Sixth Replies does not merely recapitulate the theory developed in the *Dioptrique*, but changes it significantly in ways that exacerbate rather than ameliorate his problems.

43 The way that association of ideas was used by Berkeley to explain vision is also open to the objection that when we open our eyes and look around, what we are primarily experiencing is tactual ideas (those that have been regularly associated with our ideas of light and colour). This strikes me as extremely odd.

44 *La Recherche de la verité*, Bk I, ch. 9, sect. 3.

45 I am indebted to Phil Devine for his comments on a draft of this essay, and especially for his suggestions about the nature of explanation.

22 Symposium on Descartes on perceptual cognition

Introduction

John Sutton

Descartes, the textbooks say, divided human beings, or at least their minds, from the natural world. This is not just the consequence of metaphysical dualism, but of the concomitant indirect 'ideas' theory of perception. On the standard view, the soul must dimly infer the nature of the external world from the meagre, fragmentary, and often misleading input which is causally transmitted from objects through the nervous system to the brain and, ultimately, to the pineal gland. The metaphysical solipsism of the *cogito*, on this picture, has its psycho-physiological counterpart in the way Descartes sets all goings-on in nature at such a distance from the knowing subject, who is temporarily and imperfectly united with a physical body. We cannot be sure, after all, that there are human beings rather than mere automata under the hats and cloaks we see from our window.

The epistemological focus of much twentieth-century history of early modern philosophy has, in the case of Descartes, not only led to general neglect of his natural philosophy. It has also encouraged the misreading of substantive claims in his psycho-physiological account of perception, by assuming that this account must be derived from and subordinate to the general demands of method outlined in the *Meditationes*. But the details of Descartes' theory of perception were already in place in the early 1630s: *Le Monde*, including *L'Homme*, offers both a general theory of representation, and a set of specific psycho-physiological hypotheses about the operation of the senses. There is little evidence that Descartes was at this stage deeply moved either by epistemological scepticism or by the need to demonstrate the immortality of the soul. Further, as this symposium seeks to confirm, careful reading of Descartes may suggest a theory of perception quite unlike the caricature: Descartes' 'ideas', whatever they are, are not simply passive reflections of the external world.

The symposium consists of four papers which take up different aspects of an interpretation of Descartes' theory of perception which has been developed over some years by John Yolton. The papers are followed by a response from Yolton which addresses the central criticisms of his interpretation, and seeks to develop it further. Many philosophical discussions of perception run aground on tired disputes between 'direct realists', who see perception as immediate awareness of the world, and 'indirect' or 'representative realists', who argue that there can be no such awareness without the involvement of some kind of mediating representation in cognitive processing. While Yolton is sympathetic to direct realism, his work seeks to offer genuine alternatives to extreme versions of either position.

Yolton hopes that careful discussion of the history of theories of perception 'may even offer some resolutions to questions about representation and realism'.[1] He disputes the standard historical narrative which laments 'the original sin of modern philosophy' in the seventeenth-century 'invention' of ideas as dubious reflections or representations of the world, cutting us off from a newly veiled reality[2]: for Yolton this 'way of ideas' story was a convenient target invented by Thomas Reid, a story which smooths over considerable diversity in the earlier traditions.[3] He claims instead to find, in an interpretation of Descartes which Yolton shares with Arnauld, a philosophically significant version of direct realism which still allows a role to a certain kind of representing in perception.

On this view, ideas are not the objects of perception, but are acts of perceiving, and thus are not intermediaries between mind and world at all. The relation of representation holds not between an idea–object and a physical object, but between an act of perceiving and a physical object: thus, the hope is, 'the indirectness traditionally associated with representative theories disappears'.[4] Yolton's first significant claim is that ideas as acts of perceiving do not themselves signify objects. How then are they involved in perception? Ideas are not themselves signs, but are cognitive or interpretive responses to signs. In his second central claim, Yolton argues that the signs in question are the physiological motions in nerves and brain to which, according to a 'natural geometry', cognitive responses arise.[5]

So in Yolton's version of Descartes' account, there is still room for representation, or perhaps 'representing'. According to traditional divisions, one mark of an indirect realist theory is that it postulates a two-stage cognitive process in perception: first, there is some direct awareness of an idea or trace, then by inspecting this idea the subject somehow *indirectly* infers the way the world is. But Yolton does not posit direct awareness of brain motions: it is indeed hard to see how such motions could be immediate objects of experience which the subject then puts to use in a conscious inference. David Behan's chapter below, which places Descartes' account of perception in the context of the sophisticated and diverse theories of perception in late scholastic philosophy, shows how close Descartes is here to the notion of a 'formal sign', which is not itself an object of knowledge, but by means of which we know something else. Behan demonstrates that the scholastics who employed this notion were confident that the use of formal signs in an act of cognition does not thereby render that act mediate in an epistemologically problematic sense.

But some critics, keen to convict Descartes of incoherence, take him to accept direct consciousness of images etched on the pineal gland. J.J. Gibson's biographer Edward Reed, for example, argues that, because Descartes believes that 'all existing thoughts are consequences of the motions of the brain', he must also accept that 'all awarenesses are awarenesses of brain states'.[6] However this does not inevitably follow. Descartes does insist, in a number of passages discussed throughout this symposium, that ideas do not resemble their objects. As Yasuhiko Tomida argues below, the corpuscularian theory of matter shared by Descartes and Locke entails that the world of appearances differs from the physical world. The compatibility of this natural philosophy with any direct realist commitment to the immediate perception of macroscopic objects is debated by Tomida and Yolton;[7] but there is no reason to think that the rejection of representation-by-resemblance requires that we only ever see our own brains. As Nancy Maull puts it, the 'elaborate optical plumbing' involved in generating judgements about distant objects 'does not imply that the soul is aware of a pineal pattern'.[8]

For Yolton, the great advantage of his account is that it offers at least the beginnings of an alternative to merely naturalistic causal theories of perception. The causal relations in operation between physical objects and brain motions are not sufficient for perceptual cognition: there must also be a distinct cognitive, significatory, or semantic relation in operation between those brain motions and the idea–acts which interpret them. Although Yolton on occasion wonders if causal and cognitive relations could be compatible or work in tandem,[9] his considered view in *Perception and Reality*[10] is that there are only significatory, and not causal, relations running to the mind from the physical world. In his paper, Peter Slezak takes issue with this central claim, arguing that a better interpretation of Descartes offers a purely causal account of perception, which moreover is philosophically preferable to Yolton's non-mechanistic alternative.[11]

Even if, as Yolton believes, Descartes' account does not rely on static idea–representations cutting us off from reality, there remains a further question about the operation of this natural geometry. If we are not consciously aware of brain motions in responding cognitively to them, must there not be some inner interpreter to which perceptual capacities are attributed. This is a central charge of Celia Wolf-Devine's contribution below: she claims that accounts of perception in terms of the unconscious operation of natural signs must, despite disclaimers by both Descartes and Yolton, invoke an inner homunculus to interpret those signs. That there remain problems about bridging the gap between the causal and the cognitive on Yolton's account is not surprising; as both Slezak and Wolf-Devine acknowledge, even the naturalistic consensus in cognitive sciences has failed to bring us much closer to a solution. Both Yolton's work and this symposium contribute to an approach to perception in which historical interpretation and contemporary theory may illuminate each other.

Notes

1 John Yolton, 'The Way of Ideas: a retrospective', *Journal of Philosophy* vol. 87 (1990), 510–6: 516.
2 Richard Rorty, *Philosophy and the Mirror of Nature* (Oxford, 1980), ch. 1: the quotation is from 60 n.32.
3 Yolton, *Perceptual Acquaintance from Descartes to Reid* (Minneapolis, 1984), ch. 11.
4 Yolton, review of S. Nadler, *Arnauld and the Cartesian Philosophy of Ideas*, in *Journal of Philosophy* vol. 88 (1991), 109–12: 111.
5 Yolton, 'Mirrors and Veils, Thoughts and Things: the epistemological problematic', in A. Malachowski, ed., *Reading Rorty* (Oxford, 1990), 58–73: 62.
6 Edward S. Reed, 'Descartes' corporeal ideas hypothesis and the origins of scientific psychology', *Review of Metaphysics* vol. 35 (1982), 731–52: 733. For related phenomenological and direct realist attacks on Descartes see Marjorie Grene, *Descartes* (Brighton, 1985), 205–12; David Farrell Krell, *Of Memory, Reminiscence, and Writing* (Bloomington, 1990), 65–8; Emily Grosholz, *Cartesian Method and the Problem of Reduction* (Oxford, 1991), 129–31.
7 See also Stephen Gaukroger, 'Introduction: the background to the problem of perceptual cognition', in Gaukroger, trans., *A. Arnauld: On True and False ideas* (Manchester, 1990), 1–41: 37–39.
8 Nancy Maull, 'Cartesian Optics and the Geometrization of Nature', in S. Gaukroger, ed., *Descartes: philosophy, mathematics, physics* (Brighton, 1980), 23–40: 34
9 See for example *Perceptual Acquaintance*, 39; 'Representation and Realism: some reflections on the way of ideas', *Mind* vol. 96 (1987), 318–30: 323.
10 Yolton, *Perception and Reality: a history from Descartes to Kant* (Ithaca, 1996), see especially 183–214.
11 See also John Sutton, *Philosophy and Memory Traces: Descartes to connectionism* (Cambridge, 1998), 294–7.

22a Descartes and formal signs

David Behan

> Descartes' account of physical [brain] motions as signs is such a startling notion that one wonders about its antecedents.[1]

My purpose is to describe some of those antecedents and to show how they complement Yolton's semantic approach to Descartes on perception. At the end of this paper I suggest that application of the scholastic notion of formal signs to Descartes' non-physiological *ideae* would strengthen Yolton's claim that Descartes was not a representationalist.

Formal and instrumental signs

In Chapter V of *De Dialectica*, St. Augustine described a sign as 'what is itself sensed and shows to the mind something in addition to itself (*Signum est et quod se ipsum sensui, et praeter se aliquid animo ostendit*)'.[2] After restating his definition in *De Doctrina Christiana* II.1 ('A sign is a thing which, in addition to the species which it impresses on the senses, makes something other than itself come into the mind; *Signum est enim res praeter speciem, quam ingerit sensibus, aliud aliquid ex se faciens in cogitationem venire*'), he gave examples:

> When we see a footprint, we conclude that an animal whose footprint this is has passed by; and when we see smoke, we know that there is fire beneath; and when we hear the voice of a living man, we think of the feeling in his mind; and when the trumpet sounds, soldiers know that they are to advance or retreat, or do whatever else the state of the battle requires.[3]

As the examples make clear, a sign for Augustine was something external which one is aware of as an object. The late scholastics called such signs instrumental and contrasted them with formal signs, which were internal. Formal signs are called formal because they bring about cognition by informing (*informando*) a cognitive power.

The terminology of 'formal' and 'instrumental' occurs as far back as Giles of Rome.[4] Between Giles of Rome and Descartes, formal signs received careful treatment from the Coimbra commentators[5] and thorough treatment from Descartes' contemporary, John of St. Thomas.[6] Brief discussions of them can also be found in Fonseca,[7] Suárez,[8] and Eustache de Saint-Paul.[9] The basic point of the distinction was that while formal/internal signs play an important role in the process of cognition, they are not themselves known as objects and so are not the ultimate ending point (*terminus*) of intellective cognition. Instrumental/external signs, on the other hand, are themselves known as objects[10]:

> Sometimes the sign is something which, *itself known beforehand*, thereafter makes known another thing: a ribbon of smoke which we see going up in the air, a portrait which we see in a museum are objects on which our knowledge has its impact beforehand, later passing to other objects known by means of the former, to the fire of which the smoke is the effect and the sign, to the model of whom the portrait is the image and the sign. Such are *instrumental* signs (we could also say 'sign–things'), and this is the case with all the signs which we experience, *save* for a privileged category consisting in the mental signs which intervene in the act of knowing; an image, in imagination or in memory, a concept. Such signs the scholastics called *formal* signs (we could also say 'pure signs'); they are mental forms whose *entire essence* is to convey meaning (to signify); before being themselves known as objects (by a reflexive act), such signs are known only by the knowledge itself which by their means brings the mind to the object; in other words, in order to exercise their function as signs, they are known not by 'appearing' as an object but by 'disappearing' before the object. Mnemonic image, the mental form preserved in memory, is not *that which* is known when we remember, it is purely the means by which we know directly an event lived in the past; the concept is not *that which* is known when our intelligence is at work, it is purely the means by which we seize directly an intelligible aspect of things. Such signs are pure *élans* ('intentions', urges) of the mind toward the object. In an entirely and irreducibly original universe which is the universe of knowledge, they realize in an altogether special manner, the ideal of the perfect sign and of the perfect image; they are natural signs, natural images, and are also *pure* signs and *pure* images.[11]

When John of St. Thomas reviewed the basic Thomistic elements of (non-reflexive) cognition, he maintained that the phantasm is a formal sign, the impressed species is not, the act of conceiving (*conceptio*) is not, and the concept brought forth by the mind (*conceptus*) is a formal sign 'most properly' (*propriissime*).[12] He also noted that 'a formal sign, since it is the awareness itself or concept of a thing, does not add numerically to [does not differ from] the very cognition itself to which it leads the power.'[13]

A formal sign, then, is not itself known as an object, but it does signify something other than itself. As John Deely nicely puts it, a formal sign 'signifies without itself being objectified'.[14] A formal sign is not the basis for an inference from it to what it signifies. We do not know objects by knowing formal signs as objects; rather through formal signs we know the objects they signify.[15]

When the Coimbra commentators combined the distinction between formal and instrumental signs with that between natural and conventional signs,[16] they held that all formal signs are natural signs,[17] for natural signs present to the mind (*repraesentare*) 'the same in all people'.

Though Yolton considers Cartesian brain motions as natural signs, he does not speak of them as formal signs. Yet the formal/instrumental division of signs, shared by most of Descartes' scholastic antecedents, is quite consistent with his analysis.

Repraesentare and *significare*: the sign as *Janus bifrons*

Two related questions which arise from late scholastic discussions of signs are relevant to Yolton's semantic approach to Descartes: 'What is meant by '*repraesentare*'?' and 'How does '*repraesentare*' differ from '*significare*'?'

The late scholastics used three terms in relation to cognition: '*facere cognoscere*', '*repraesentare*', and '*significare*'. John of St. Thomas explained and ranked them. '*Facere cognoscere*' ('to make [a cognitive faculty] cognize') is the broadest, for it applies to all four causes of cognition: the efficient cause, the thing cognized, the formal cause, and the instrumental cause.[18] '*Repraesentare*' ('to present [to a cognitive power]') is used three ways: objectively, formally, and instrumentally;[19] whereas '*significare*' ('to signify') is used in only two ways: formally and instrumentally.[20]

John of St. Thomas' understanding of '*repraesentare*' as different from '*significare*' represents a common position in late scholasticism. The Coimbrans, for example, said that 'to represent is to make a thing present (*repraesentare est rem praesentem facere*)'.[21] Standard practice was to use '*repraesentare*' rather than '*praesentare*' (or '*rem praesentem facere*') because a single verb had to accommodate both intuitive and abstractive cognition, i.e. cognition of a present object and of an absent object.[22] Both presenting and re-presenting are included in '*repraesentare*'.[23]

Not all late scholastics acknowledged a difference between '*repraesentare*' and '*significare*'. Fonseca, for example, said that 'to signify is nothing other than to present something to a cognitive power';[24] so it is not unusual to find the terms used interchangeably. Yet those who did insist upon a difference (such as the Coimbra commentators and John of St. Thomas) noted that something or someone can represent (or present) either itself or something else, but can signify only something other than itself. That restriction on 'signify' reflects the '*praeter*' in St. Augustine's definitions of a sign: a sign, by presenting itself to a cognitive faculty, signifies (arouses in the mind awareness of) something other than itself.[25] As the Coimbrans put it: 'A sign is what is put in the place of a thing and arouses awareness of that thing (*signum est, quod loco rei substituitur, et ejus notitiam affert*)'.[26]

I follow the Coimbrans and John of St. Thomas by translating '*repraesentare*' as 'to present (to a cognitive power)' and '*significare*' as 'to signify (something other than oneself)'. By distinguishing those two activities I want to call attention to what the late scholastics emphasised as the twofold character of a sign: the presentative and the significative. A sign presents itself to a cognitive power and signifies something other than itself. A sign, in other words, is a *Janus bifrons* which looks in two directions. As the Coimbrans put it: 'There are two relations, or dispositions [which any sign has], one to the thing signified, the other to the power to which the sign signifies'.[27]

Yolton joins the Coimbrans and John of St. Thomas in insisting upon a distinction between *repraesentare* and *significare*, but it is not clear to me just how he understands the difference.[28] He does not seem to be speaking of what the Coimbrans and John of St. Thomas had in mind, for he does not appear to acknowledge, as they did, the two 'relations' or 'dispositions' of a sign: to the thing signified as well as to the cognitive power. For him, Cartesian brain motions are only signs to the mind which lead it to produce a sensation. But if we apply to Descartes the *Janus bifrons* analysis sketched above, brain motions not only present (*repraesentare*) themselves (as formal signs) to the mind, but also signify (*significare*) something other than themselves.

Those scholastic differences aside, I believe that what I have said is generally consistent with Yolton's position on brain motions as (formal) signs, though perhaps not with his terminology. Presentation of brain motions to the mind is the occasion for the mind to produce *ideae*.[29] Furthermore, I agree with him that the relation is not causal but semantic or, as I would prefer to put it, semiotic.

William's spider, productionism, and natural ordination

A view of perception strikingly similar to Descartes' (as Yolton interprets it and as it appears in *L'Homme*, *La Dioptrique*, and the *Notae*) can be found in William of Auvergne, who maintained that all cognition is through signs.[30] William did not explain perception by efficient causal interaction, for he adopted an Augustinian view of the soul which ruled out 'intermediaries of a semi-psychic character', such as phantasms.[31] Rather, he used metaphors to describe perception. Although these metaphors may involve instrumental (external) rather than formal (internal) signs, a semiotic rather than an efficient causal relation holds for both sorts of sign, and

Moody's analysis suggests that William was in fact talking about formal signs.[32]

What I believe William was suggesting through his metaphors was the 'productionist' theory of sensation and concept-formation which would emerge in the Port Royal Logic and be criticised by Malebranche.[33] (Formal signs, however, do not appear to be part of that later productionism.)

William's most striking metaphor was the spider and the fly.[34] The spider seems much like the blind man of Descartes' *Optics*, and the productionism implicit in William's account is consistent with Descartes' comment in the *Notae* that 'there is nothing in our ideas which is not innate [natural][35] to the mind or the faculty of thinking, with the sole exception of those circumstances which relate to experience, such as the fact that we judge that this or that idea which we now have immediately before our mind refers to a certain thing situated outside us'.[36] One of William's recent commentators describes his metaphors.

> The first compared the intellect to a spider and the sensible object to a fly caught in its web. Just as the motion of the struggling victim, passed along a filament of the web, was enough to make the spider realize it had caught a fly, even though it could not see the insect, so sensations sufficed to lead the mind to knowledge of an external substance without any direct perception. The motion in the web, like the sensations, provided the merely occasional cause of knowledge; the efficient cause lay in the innate light (*innatum lumen*) or skill (*ars, artificium*) of the spider – that is, the mind. William likened the process to the way recollections arose from the treasury of the memory or thoughts and passions from speculative or moral habits, given the proper stimulation by a suggestive object in the world.[37]

The second was Aristotle's money-changer example in the *Posterior Analytics*, which

> . . . has to do with a man watching a money-changer speak with another person. In this case the viewer, without overhearing any of the conversation or being told what was going on, would be able to guess that the two men were transacting a loan. Here, sight gave the occasion to what William, following Aristotle, called the skill or quick wit (*sol[l]ertia*) of the viewer, and this skill accounted for the knowledge of what was actually happening. William stressed that under no circumstances could the vision of two men speaking be a cause in itself of the viewer's understanding. Such knowledge could arise solely from a skill of comprehension subtle enough to take the sensible image as evidence for something in no way explicitly contained in that image. On another occasion William called this skill of Aristotle's a

> habit or disposition (*habitus*). It was, as he described it, a spring from which perceptions poured forth like a stream flowing from its source.[38]

In addition, William likened the mind to a chameleon and an ape.

> . . . [H]e explained that the intellectual power was *by nature (nata est) able* to receive the signs of things, the mental images by which it knew them, and that to do so it needed the mere excitation of sensation, not, so the text implied, a true act of the senses on the mind. Given these fundamentals of cognition, William next turned to specify how the powers of the mind operated. He noted that the senses functioned by applying the mind to things in the world, joining it to them by means of a spiritual connection (*conjunctio spiritualis*). As for the operation of the intellect itself, it could be compared to the behaviour of two animals: like the chameleon, the mind picked up or took into itself the similitude [sign][39] of any object to which the senses directed it; like the ape, which imitated what it saw men do, the mind made itself like any object exposed to it.[40]

Descartes did not appeal to a *conjunctio spiritualis*,[41] and in Meditation VI he admitted that 'there obviously is not any bond of union – at least one which *I* might understand [*ego intelligam*] – between that twitching [in my stomach] and my wanting to eat, or between the [physical] sensing of the object which is the occasion of the pain [in my mind] [*dolorem inferentis*] and the feeling [*cogitationem*] of distress which arises [in my mind] from that sensation [of pain]'.[42] Nevertheless, he did insist that the relationship between the mind and the physical world was 'ordained by nature'.[43]

The semiotic relation and natural supervenience

It might seem that the semiotic (or semantic) relation rather than an efficient causal relation (interaction) does not clarify the mind–body problem in Descartes, but only 'explains' the obscure through the more obscure. In fact, however, the semiotic relation does not explain efficient causal interaction because it does not operate by efficient causation. For the late scholastics it involved specificative causality.[44] And if Descartes had adopted the semiotic relation, we can make sense of his refusal to deal seriously with interaction in terms of efficient causation. The semiotic relation was standard fare for many late scholastics,[45] and it was developed to a high degree of sophistication by John of St. Thomas. It would not be surprising if Descartes had employed it without being able to explain its workings, for we have no evidence that he read John of St. Thomas. Yet he must have encountered at least its rudiments in Eustache de S. Paul's mentions of formal and instrumental signs, and it is very likely that he had been exposed to some of its intricacies if, in his first year (1611–12) of the philosophical curriculum at La Flèche, he read the Coimbra commentary on Aristotle's *De Interpretatione*.[46]

I believe Descartes did employ the semiotic relation in his theory of sense perception without a careful knowledge of its workings. His mention of natural ordination in sense perception involved psycho-physical laws and the natural supervenience of the mental on the physical (brain motions). Were the workings obscure? Yes, but some things have to remain that way. Here is how Chalmers put it:

> One occasionally hears a fifth objection to dualism, which is that it cannot explain how the physical and the nonphysical interact. But the answer to this is simple on the natural supervenience framework: they interact by virtue of psychophysical laws. There is a system of laws that ensures that a given physical configuration will be accompanied by a given experience, just as there are laws that dictate that a given physical object will gravitationally affect others in a certain way. It might be objected that this does not tell us what the *connection* is, or *how* a physical configuration can give rise to experience. But the search for such a connection is misguided. Even with fundamental physical laws, we cannot find a 'connection' that does the work. Things simply happen in accordance with the law; beyond a certain point, there is no asking 'how'. As Hume showed, the quest for such ultimate connections is fruitless. If there are indeed such connections, they are entirely mysterious in both the physical and psychophysical cases, so the latter poses no *special* problem here. It is notable that Newton's opponents made a similar objection to his theory of gravitation: *How* does one body exert a force on another far away? But the force of the question dissolved over time. We have learned to live with taking certain things as fundamental.[47]

Descartes would not have accepted the scientific instrumentalism implicit in Chalmers' remarks, and he apparently did not stop, as Chalmers does, at property dualism.[48] But those are minor issues given the major problem the semiotic relation presents to Descartes' scientific realism: the possibility that the psycho-physical laws behind natural ordination and the semiotic relation may not yield veridical perception. To solve that problem, Descartes had to show that the *author* of those laws and the creator of human cognitive faculties could not be unreliable (*Deus non sit fallax*). He did that in the *Meditationes*.

Physiological and non-physiological *ideae* as formal signs

Descartes spoke of brain motions, when they function as formal signs, as *ideae*. These are 'ideas/images of the imagination' rather than 'ideas of the pure mind'.[49] They are ideas/images attributed to the common sense,[50] imprinted 'in the organ of the "common" sense [the pineal gland] and the imagination'.[51] They are the '*figuras vel ideas*' of Rule XII,[52] the 'movements in the brain, which cause the soul to have sensory perception of the objects',[53] 'the images of material things which are depicted in the corporeal imagination'.[54] They are the 'forms or images which the rational soul united to this machine will consider directly [*immediatement*] when it imagines some object or perceives it by the senses'.[55] These *ideae*, Descartes told Burman, are equivalent to the scholastics' *phantasma* or *idola*.[56] These *ideae* have been Yolton's main concern in his discussion of perceptual acquaintance.

In their role as formal signs, motions in the brain fall under Descartes' general notion of an *idea* taken *formaliter* as a sign[57] and, because of their location in the brain, might be called his physiological *ideae*. But in addition to physiological *ideae* there are Descartes' non-physiological *ideae*, '*ideae* of the pure mind', those produced by the mind itself. Though editorial limitations do not allow me to develop it here, I suggest that those non-physiological *ideae* (taken *formaliter* as signs rather than *materialiter* as mere operations of a cognitive faculty) are also formal signs. Yolton seems reluctant to acknowledge that Descartes' non-physiological *ideae* (taken *formaliter*) are signs at all. Yet to regard them as formal signs would, I think, strengthen his claim that Descartes was not a representationalist.[58]

Notes

1 John W. Yolton, *Perception and Reality: A History from Descartes to Kant* (Ithaca, 1996).

2 Unless otherwise indicated, all translations are my own. My interpolations are within brackets.

3 St. Augustine, *On Christian Doctrine*, trans. J.F. Shaw (Chicago, 1955), 636–7.

4 Doyle notes that: 'As the *Conimbricenses* see it, earlier Scholastics did not have an explicit notion of a formal sign, although they did in various ways grasp the reality of the division. The first one *explicitly* to speak of "formal signs" in this context was Giles of Rome (1243–1316) who is quoted [by the Coimbrans] as saying: "Everything by the mediation of which we know something else, necessarily is either itself first known by us or not. If it must be first known, it is an instrumental sign – if not, then it is a formal sign." (*Coimbricenses* 1607: q. 2, a. 3, p. 29).' (John P. Doyle, 'The *Conimbricenses* on the Relations involved in Signs', *Semiotics* (1984), 567–76: 571.) In the 1976 Olms Verlag reprint of *Commentarii Collegii Conimbricensis e Societate Jesu in universam dialecticam Aristotelis*, the passage Doyle translates occurs in q. 2, a. 1 of *In De Interpretatione* (col. 17). It reads: '*Omne id, quo mediante aliud cognoscimus, aut necesse est a nobis prius cognosci, aut non, si debet cognosci, est instrumentale signum; sin minus, formale*'. The next sentence reads (with emphasis added) '*Quod idcirco formale dicitur, quia causat cognitionem* informando*, aut in ratione termini, aut in ratione principii, ut mox dicemus* (It is called formal, because it brings about cognition by informing, either as a terminus or as a source, as we will soon point out)'. Earlier (q. 1, a. 1, col. 9): '. . . *signum formale, & instrumentale sunt duae signorum species in hoc dissidentes, quod unum percipitur a potentia: aliud non percipitur* (. . . the formal sign

and the instrumental sign are two species of sign differing in this, that one is perceived by a [cognitive] power and the other is not)'.

5 See ch. 1 (*De Signis*) of Conimbricenses, *In De Interp.*

6 See John of St. Thomas (John Poinsot) in John of St. Thomas (John Poinsot), *Tractatus de Signis*: *The Semiotic of John Poinsot*, Interpretive Arrangement by John N. Deely in consultation with Ralph Austin Powell (Berkeley, 1985). This is part of John of St. Thomas' *Cursus Philosophicus Thomisticus* (1631–5).

7 Petrus Fonsecus, *Institutionum Dialecticorum Libri Octo* (Conimbricae, 1575, reprint edited by J.F. Gomez, Coimbra, 1964). See Book I, Chapters 8 and 10 in the translation of Luigi Romeo, 'Pedro Da Fonseca in Renaissance Semiotics: A Segmental History of Footnotes', *Ars Semiotics* vol. 2 (1979), 187–204. The first sentence of Romeo's translation of Chapter 10 should read, 'To commence, concepts are formal signs. . . '.

8 The heading for Book II, Ch. 26, section 10 of Suárez's *De Angelis* (1620; *Opera Omnia*, ii. 237) reads: *Secunda interrogatio, an dicta signa sint naturalia vel ex instituto – Signi formalis, et instrumen. – Distinctio.* Suárez makes it clear, however, that the distinction of the dialecticians between instrumental and formal signs is for him the distinction between a means of cognition (*medium cognoscendi*) which is itself cognized (*cognitum*) and one which is not itself cognized (*incognitum*) (Suárez: *De Angelis* II.26.10; *Opera Omnia* ii. 237–8).

9 Eustache de Saint-Paul, *Summa philosophiae quadripartita* (P. Alberti: Geneva, 1638), Part I (*Dialectica*), *Tractatus* 1, *Quaestio* 2 (*Quinam sint termini ex parte materiae?*), p. 17, and Part III (*Physica*), *Tractatus* 3, *Disputatio* 1, *Quaestio* 2, pp. 230–1 (cited in Étienne Gilson, *Index Scolastico-Cartésien* (Paris, 1912) #169).

10 Nuchelmans described the distinction as it was drawn in terms of images by John of St. Thomas in 1632: 'Johannes a Sancto Thoma draws a distinction between two kinds of image. An exterior and instrumental image, such as a portrait, causes one to think of some person or thing by being first perceived itself (*talis imago prius debet attingi et cognosci quam obiectum ipsum*). An interior and formal image, on the other hand, is not itself an object of knowledge, but only the [intelligible nature (*ratio*) and] form according to which the act of thinking is directed towards a certain object in the world (*ipsa est ratio et forma terminans cognitionem, et haec non debet esse cognita obiective, sed solum cognitionem reddere terminatam formaliter respectu obiecti*). It is only in the latter sense that the abstract form in the mind can be called an image or representation.' (Gabriel Nuchelmans, *Judgment and Proposition from Descartes to Kant* (Amsterdam, 1983), 12.) In dealing with concepts or mental words (*verbum mentis*) as images (*imagines*), John of St. Thomas considered an objection which simultaneously requires and rejects representationalism. He stated the objection, originally raised against the *verbum mentis* (or *idea* or *conceptus*) as *imago* by, among others, Durandus of St. Porcain, in terms of *ideae* or concepts. (For Durandus' objection, see Robert Pasnau, *Theories of Cognition in the Later Middle Ages* (Cambridge, 1997), 17–18.) 'Since no one finds that he first sees this image [mental word] and as a result sees the [external] object in it, how could a mental word serve for cognizing an [external] object if the mental word has not already been cognized [objectively] as a representing image; but then how could the mental word be formed in virtue of the cognition [of an external object] if the cognition itself sees the object only insofar as it is represented in the mental word itself.' The answer, John said, lies in the distinction between formal and instrumental images: 'An image can be taken in two ways: The first is exterior and instrumental, which, when cognized, leads to the cognition of an [external] object, and an image of this sort does already have to have been perceived and cognized as an object itself. The second is interior and formal, which is not itself an object cognized, but the image is an intelligible nature [*ratio*] and a

form [*forma*] bringing to an end the [internal] process of cognition, and this sort of image does not have to be cognized as an object.' John of St. Thomas, *Cursus Philosophicus Thomisticus*, Part IV: *Philosophiae Naturalis*, Q. XI, art. 2: *De Intellectione et Conceptu* (Reiser edition, iii. 358–9).

11 Jacques Maritain, *Redeeming the Time* (London, 1943), 195–6.

12 See John of St. Thomas, in Deely, 'Tractatus', op. cit., 247 (phantasm), 255 (impressed species), 263 (cognitive action), and 246 (concept as formal sign *propriissime*).

13 '. . . *Quia signum formale, cum sit ipsa notitia vel conceptus rei, non ponit in numero cum ipsamet cognitione, ad quam ducitur potentia*.' (John of St. Thomas, in Deely 1985, op. cit., 222).

14 John Deely, *New Beginnings: Early Modern Philosophy and Postmodern Thought* (Toronto, 1994), 35, n. 6.

15 John of St. Thomas notes that knowledge by concepts as formal signs allows immediate cognition of an object: '. . . [S]omething is said to be known equally immediately when it is known in itself and when it is known by means of a concept or awareness; for a concept does not make cognition mediate.' (John of St. Thomas, in Deely, 'Tractatus', op. cit., 222–3; Deely translation). 'Likewise, a concept does not make a cognition mediate, but immediate; for we understand the objectified thing in itself immediately, albeit we understand by means of a concept and an awareness.' (John of St. Thomas, in Deely, 'Tractatus', op. cit., 231; Deely translation).

16 'A natural sign is one which presents as a result of the nature of an object, apart from any decision or custom; and so it presents the same in all people, as smoke presents fire. A conventional sign is one which presents something as a result of a decision of the will by a public authority, such as the external word "man". A customary sign is one which presents as a result of a customary practice alone without public decision, as napkins on the table signify the midday meal.' (John of St. Thomas, in Deely, 'Tractatus', op. cit., 27)

17 '(1) For the *Conimbricenses* no formal sign is conventional. . . . Therefore every formal sign is natural. . . . (2) Not every natural sign is, conversely, formal. Some, e.g. smoke, are evidently instrumental. (3) Every conventional sign is instrumental. It must be itself first known in order to lead to the knowledge of something else. And (4) not every instrumental sign is conventional. Again the example of smoke is illustrative.' (Doyle, op. cit., 571).

18 See John of St. Thomas, in Deely, 'Tractatus', op. cit., pp. 25–6.

19 ' "To present [to a cognitive power] [*repraesentare*]" is used of each factor by which something is made present [*fit praesens*] to a [cognitive] power, and so it's used in three ways: objectively [*objective*], formally [*formaliter*], and instrumentally [*instrumentaliter*]. An object presents itself objectively [*objective*], as the wall of a house does; an awareness [concept] [*notitia*] presents formally [*formaliter*]; a trace presents instrumentally [*instrumentaliter*].' (John of St. Thomas, in Deely, 'Tractatus', op. cit., 26–7).

20 ' "To signify [*significare*]" is used of that by which something distinct from itself is made present [*fit praesens*], and so it's used only in two ways, i.e. formally and instrumentally.' (John of St. Thomas, in Deely, 'Tractatus', op. cit., 27).

21 *In Libros Aristotelis De Interpretatione*, in *Commentarii Collegii Conimbricensis e Societate Jesu in universam dialecticam Aristotelis* (Koln, 1607) I.1,2, col. 11.

22 See John of St. Thomas, in Deely, 'Tractatus', op. cit., 29.

23 The sense of '*repraesentare*' as 'to make present' or 'to present to the mind' carried over into the seventeenth century. Tom Lennon, speaking of a passage in Malebranche, remarks in a footnote '. . . Malebranche here uses the term "represent" in its neutral seventeenth-century meaning, "make present" '. (Thomas M. Lennon, 'Representationalism, judgment and perception of

distance: further to Yolton and McRae', *Dialogue*, vol. 19 (1980) 151–62: 162 n. 28.)

24 '. . . [*S*]*ignificare nihil aliud est, quam potentiae cognoscenti, aliquid repraesentare*' (Fonseca, *Institutionum Dialectorum*, ch. 8, p. 34). 'Everything representing something is a sign of what is represented, hence whatever represents something is at the same time a sign.' (Fonseca, *Institutionum Dialectorum*, ch. 8; Romeo translation in Luigi Romeo, 'Pedro Da Fonseca', 194.)

25 'Poinsot expressly denies the equation (explicit in Fonseca and implicit in most writers on signs down to the present day) between *representation* and *signification*. . . . Representation and signification differ in this: an object can represent another than itself, and thus be a sign, but an object can also represent itself; whereas it is a contradiction for a sign to be a sign of itself: a sign is a sign only if it is a sign of something at least modally other.' (John Deely: *Introducing Semiotic*: *Its History and Doctrine* (Bloomington, 1982), 61). The Coimbrans made the same point: *In De Interp.*, 1.1,2, cols 14–15.

26 Coimb: *In De Interp.*, 1.1,1, col. 8.

27 Coimb: *In De Interp.*, 1.1,1, col. 8. See also Coimbra: *In De Interp.*, 1.1, 2.

28 See, for example, Yolton, *Perception and Reality*, 190.

29 In the terminology of Peircean semiotics, formal signs are indexical rather than iconic. Since the purpose of my contribution to this symposium is to describe antecedents to Descartes' account of physical motions as signs, I have not used any of the terminology of contemporary semiotics.

30 See William of Auvergne, *De Anima* VII.6, in Guilielmi Alverni, *Opera Omnia* (2 vols, Paris, 1674) ii. 211.

31 E.A. Moody, *Studies in Medieval Philosophy, Science, and Logic*: *Collected Papers 1933–1969* (Berkeley, 1975), 46: 'That sense perception cannot be a modification of the soul by corporeal things, and that it must be, in the last analysis, an activity of the soul, follows from William's definition of the soul's relation to the body as unilateral, and as analogous to the relation of God to the creation. For William of Auvergne, as for St. Augustin, it is unthinkable that what is corporeal and inanimate should be able to affect and modify, by its proper corporeal powers or actions, that which is spiritual. Spirit does not suffer passion in the sense that bodies do – it is not alterable by the action of corporeal agents. Such a principle gives rise to difficulties of its own; but at least it enables William to escape the insuperable difficulties attendant upon a causal theory of perception, where the external object is supposed to produce a perception of itself in the soul through a series of corporeal events in the sense organs, nervous system, and brain. Intermediaries of a semi-psychic character are of no more value in explaining sense perception than they are in explaining the movement of the body by the soul.'

32 For an excellent description of William's semiotic theory of cognition, see Moody, op. cit., 46–58. Though Moody does not use the term 'formal sign', he describes it in his account of William's theory of perception: 'In what, then, does perception consist? It is not a motion nor the result of a motion; it is not even a necessary part of the process which commences with the physical alteration of a sense organ, and terminates in a bodily motion or reaction. The answer to this question is to be found in William's statement that all cognition is through signs. . . . This does not mean that what we know is the sign rather than the thing signified; if this were the case, we would know the sign itself only by another sign, and so on *ad infinitum*. What it does mean is that the thing known is in the soul according to the mode of being of the soul, which is cognitive. To know a tree is something different from being a tree; if a man could become a tree, he would put forth leaves, but he would not know. Knowledge is by signification, and what is known is that which is signi-

fied rather than the symbol or act by which it is signified.' (Moody, op. cit., 51–2).

33 See Steven Nadler, *Malebranche and Ideas* (Oxford, 1992), 115–25, for a description of the productionist theory.

34 William's spider metaphor, along with the money-changer, appears in his *De Universo* (Part II, ch. 75), in Auvergne, *Op. Om.,* Vol. i. 928. Here is Moody's translation of the passage (in Moody 1975, p. 76): 'Thus the apprehension, as I said, of the spider with respect to the capture of the fly, is occasioned by the motion or concussion of a thread in his web, but it is effectively or efficiently caused by an innate light, or by an art naturally implanted in the spider. Just as you may see reminiscences and recollections issue forth from the store-house of memory, similarly cognitions and affections (issue forth) from the habits of the sciences, and of the virtues and vices, by the lightest stimuli of external occurrences. This is seen in the example which Aristotle gave of the mental aptitude (*solertia*), i.e., of the man who sees someone talking with the money-changer, and from this concludes that he wishes to get some money changed by him. Here this sight gives the occasion to the quick-witted mind, so that out of it comes this thought, or suspicion. However, it is manifest that the view itself could not in itself be, in any way, the cause of this opinion or suspicion; on the other hand there is no doubt that it is something of an *occasion*, and that as a kind of help (*adminiculum*) it favors the formation of the opinion. But the quick-witted is in itself the *cause* of the formation of the thought, which issues forth from it like an overflow, or like a stream from its source.' The spider can also be found in William's *De Anima* V.7 (*Opera Omnia*, ii. 122).

35 '*Innata*' can be used both by production theorists (soft innatists) and innate idea theorists (hard innatists). Nadler succinctly describes the difference: 'While on the production theory all ideas are "innate" in the trivial sense that all ideas arise from the faculty of thinking alone, and none are literally conveyed into the mind from the external world, the innateness doctrine . . . holds that the soul does not itself produce ideas but rather that God creates and places preformed ideas in the soul.' (Nadler, op. cit., 125).

36 *Notae* AT VIII-B. 358. See Descartes' comments on Regius' twelfth through fourteenth articles in *Notae* (AT viii-B. 357–60).

37 Steven P. Marrone: *William of Auvergne and Robert Grosseteste*: *New Ideas of Truth in the Early Thirteenth Century* (Princeton, 1983), 62.

38 Marrone, op. cit., 62–3. Marrone adds: 'Instead of implying a role for God [as Gilson has suggested], William's examples of a spider, a money-changer, or a fountain emphasized how sensation performed the role only of stimulating knowledge, not of causing it in the sense of generating it or even accounting for its generation. They indicated that sensations were not gratuitous, for they stimulated the mind to a determinate act; somehow they passed along to the mind enough of an indications of the object to allow the formation of a valid concept. Nevertheless, the productive cause of knowledge, that which really accounted for its presence in the intellect, was the mind itself, or more specifically some skill possessed by the mind. The analogy of the spider suggested that there was a sort of stock or treasury out of which were drawn mental perceptions; that of the money-changer, that there was more simply an ability to make the right perception under the right conditions.' (op. cit., 65).

39 For William of Auvergne, *similitudines* are (formal) signs. See Moody, op. cit., 76–7.

40 Marrone, op. cit., 66–7, emphasis added. For William's text (in *De Anima*, VII.9), see Auvergne, *Op. Om.*, ii. 215; it is also reprinted in Marrone, 294.

41 '*Spiritualis*' can be understood as 'intentional' (see Anthony Kenny, *Aquinas on Mind* (London, 1993), 34 and Pasnau, op. cit., 14, as well as Pasnau's other

index entries for 'spiritual existence (alteration, reception)'), in which case one can say that for Descartes there is an intentional ('spiritual') connection between the mind and things in the world.

42 AT vii. 76.

43 See '*instituée de la Nature*' in, for example, Discourse Six of *La Dioptrique*, AT vi. 130, 134–135, 137 and in *Passions of the Soul*, AT xi. 357, 361 (*'naturellement jointe'*), 368 (*'joint par la nature'*), 369 (*'selon l'institution de la nature'*) (CSM I.342, 344 ('joined by nature'), 348).

44 John Deely notes that 'the type of causality which best explains the action of signs is ... extrinsic formal causality of the specificative or 'objective' type' (Deely, *New Beginnings*, op. cit., 170), i.e. 'specificative causality' (ibid., 161–2 and 170–8). Maritain had earlier described the real relation of the sign to what it signifies: 'The relation of the [natural] sign to what it manifests is a real relation, i.e., is founded in reality in the case of a natural sign, since a natural sign is better known than that which it manifests, and since the property of being more knowable, and this in relation to something else that is thereby made knowable, is a real property, not a purely ideal relation (*relatio rationis*) existing as such in thought only. The fact that smoke gives us knowledge of fire rather than of water, and that tracks of oxen give us knowledge of the ox rather than of man, and the concept of a horse of the horse rather than of a stone – all this is based on a real intrinsic proportion between these signs and the things they signify. This realistic notion of the natural sign rests, in short, on a metaphysics for which intelligibility and being are consubstantial (*verum et ens convertuntur*). This real relation is not one of efficient causality. Sign strictly keeps to the order of 'objective causality' or of the formal causality of knowledge, not of efficient or productive causality. When a sign produces an effect it is never by virtue of being a sign. The sign is not even the efficient cause of the knowledge of the thing signified; it makes it known only by standing in lieu of the object within the cognitive faculty to which it brings the presence of the object, thus functioning in the same line of causality as the object itself.' (Jacques Maritain, 'Language and the theory of sign', abridged version in John Deely, Brooke Williams, and Felicia E. Kruse, eds., *Frontiers in Semiotics* (Bloomington, 1986), 51–62.) This passage contains references to relevant passages in John of St. Thomas found in Deely, 'Tractatus', op. cit.; they are pp. 194 (lines 31–37), 195 (lines 3–9, 18–29), and 202–3 (lines 46–14).

45 In addition to the standard sources I have mentioned (including Eustache de S. Paul), it can be found in Ockham after he abandoned the *fictum* theory. See Pasnau op. cit. 103–4. Pasnau suggests that it can be found even in Aquinas (ibid., 102).

46 Stephen Gaukroger points out that in 1611 Descartes 'entered the first year of the "philosophical" curriculum' (Gaukroger, *Descartes, An Intellectual Biography* (Oxford, 1995), 52) and that the curriculum included Aristotle's *De Interpretatione* (ibid., 53–4). Given the fact that Aristotle was read through the Coimbra commentaries (as well as those of Fonseca and Toledus), it is possible that Descartes had been exposed to ch. 1 (*De Signis*) of the Coimbra *In De Interp.* If he had read it in those early years, it would not be surprising if he did not recall from 1611–12 all of its details in his later philosophic writing.

47 David J. Chalmers, *The Conscious Mind* (New York, 1996), 170–1.

48 Yolton suggests that we temper 'Cartesian dualism' and pay attention to the 'intimate union that constitutes humans' (*Perception and Reality*, 69). Given his use of precisive abstraction, Descartes might not have been a 'Cartesian dualist'.

49 Descartes to Mersenne, July 1641, AT iii. 395. See also AT iii. 392–5.

50 *L'Homme* (AT xi. 177).

51 *L'Homme* (AT xi. 202).
52 *Regulae* (*Regula* XII) (AT x. 414).
53 *Passions* I, §23 (AT xi. 346).
54 Third Set of Objections with Replies (AT vii. 181).
55 *L'Homme* (AT xi. 177).
56 *Conversation with Burman* (AT v.156).
57 'By the term "*idea*" [as it refers to an *idea* taken *formaliter*, as a sign,] I understand that form [formal sign] belonging to any cognitive action, by direct grasp of which we're aware of that particular cognitive action; and so I'm not able to express anything by [external] words – understanding what I'm saying – unless it's definite that there is within me an *idea* of what is signified by those [external] words. And so I don't just call images [*imagines*] [phantasms or brain motions] painted in the corporeal imagination [formal] signs [*ideas*]; in this context I don't call those images [formal] signs [*ideas*] at all as they're just within the corporeal imagination, i.e. painted in some part of the brain, but only as they inform [*informant*] the mind itself when the mind turns to that part of the brain.' (Descartes: Second Replies, AT vii. 160–1). Descartes' term '*informant*' echoes the '*informando*' in the Coimbra commentators' description of a formal sign (see note 4 above).
58 It is not clear how far Yolton wants to go in reading Descartes as an epistemological direct realist, and care must be taken in moving from formal signs to realism. John Deely warns that the doctrine of formal signs does not necessarily lead to 'realism' (see Deely, *New Beginnings*, op. cit., 83, n. 38). Yolton also sounds a cautionary note about direct realism (*Perceptual Acquaintance*, 11).

22b Descartes' startling doctrine of the reverse-sign relation

Peter Slezak

Introduction

In Yolton's view, Descartes is to be credited with having introduced an entirely novel and remarkable doctrine of mental representation. Noting that it has received very little attention, Yolton characterises this significatory relation as a 'curious and 'somewhat obscure' doctrine which turns the conventional account on its head.

> Descartes' account of physical motions as signs is such a startling notion that one wonders about its antecedents. Philosophers before Descartes talked of signs, but I am not aware of any who reversed the normal sign relation.[1]

In his chapter on 'The semantic relation', Yolton reports Descartes' account of perception in *Le Monde*, taken to illustrate this 'second interactive relation, the semantic or significatory relation'.[2] Yolton distinguishes this from the more familiar representative relation between an idea and its object, that is, the standard conception of intentionality associated with the sense and reference of symbolic representations. In explaining the novel conception, Yolton cites Descartes' comparison of this new natural reverse-sign relation with the way in which tears and smiles convey sadness and joy, the point being that in both cases the signs perform their function despite failing to resemble that which they signify. Yolton says,

> This last suggestion should be examined carefully; it is a reversal of what we might expect. The expectation from what Descartes has been saying is that ideas or sensations are going to be signs; thus, the sensations of light would be a sign of specific motions in the object and air. His problem would accordingly be to explain how we can get information about the world from our ideas and sensations. But the sign relation here suggested is the other way around: the physical motion is the sign *of* or *for* the sensation.[3]

He explains that, on this view, 'the physical stimulus signifies the idea',[4] instead of the other way around as we should expect. Yolton follows Alquié, suggesting that 'it is clear' that for Descartes 'the physical action of light signifies to us the sensation that we feel' and, therefore, in Alquié's words, '. . . that which we habitually consider as the signified (the physical action) becomes here that which signifies'.[5] This is, then, the reverse-sign relation which Yolton takes Descartes to be offering as a radically novel account of mental representation. However, the very features which make this such a 'startling' view are, at the same time, grounds for being cautious about attributing it to Descartes. That is, what makes the doctrine startling is *ipso facto* what makes it implausible – both intrinsically as an account of the phenomenon in question and also, consequently, as an account of Descartes' intentions. Such independent considerations of implausibility cannot be decisive from an exegetical point of view, but I will suggest that the textual support for Yolton's reverse-sign interpretation is hardly compelling either.

In general, Stephen Gaukroger[6] urges us to be circumspect about Yolton's Arnauldian interpretation of Descartes on perceptual knowledge, but he appears prima facie to accept the attribution of a reverse-sign doctrine. At least in one place his exposition of Descartes' view is expressed in terms precisely reflecting the reverse-sign interpretation[7]:

> The sign here is the rotational motion of the fine corpuscles making up the ray, and what we experience when we grasp the sign is the light. In more general terms, physical motion is the sign, and what is signified is what is experienced in the sensation.[8]

Undeniably this turns the usual representational relationship on its head: generally one takes the sensation or experience to be a mental representation or sign of something, and the external physical motions to be its referent or that which is signified.

Using the term 'sign' exclusively for Descartes' novel conception, Yolton explains the point of the reverse-sign relation by saying that this new significatory relation 'replaces the *causal* relation between physical motion and ideas, but the *representing* relation goes, as it were, outward from awareness'.[9] In this sense, then, 'ideas are not signs of things; they are the interpretations of physical motion (of things)'.[10] Thus, Yolton says that the cognitive, interpretative function of ideas and sensations is representation, presumably in the more familiar sense, and not signification, which is reserved for the reverse-sign relation.

I believe that this entire scheme is unnecessarily confusing in ways which may be overcome when we recognize Descartes as striving to resolve perplexities which still bedevil debate on representation. In this sense, I will suggest that there is a certain ambivalence in Yolton's treatment of this question, and that he has perhaps not gone far enough in the direction which his own analysis dictates. Ironically, Yolton's analyses of the history of the 'idea' idea show the way to a clarification of the obscurities which attend his own account of the reverse-sign relation. Specifically, I will suggest that Yolton relies on a notoriously vexed triadic notion of representation as a relation between referent, representation and agent, but, at the same time, recognizes its problems and elucidates important alternatives to it. In other words, the very notion of a 'reverse-sign' relation preserves a certain problematic conception of representation whereas, arguably, Descartes' intention is precisely to articulate an alternative. Yolton himself clearly indicates this crucial insight where he explains that '. . . knowing (perceiving) is not reading off from our sensory or perceptual experiences properties of the world. Perceptual knowing is the having of these experiences.'[11]

I believe this is the key to the puzzles of representation from Descartes' time to our own. It is the Arnauldian direct realist view of perception as a cognitive process rather than as involving access to intermediate objects. Yolton appears sympathetic to this view, but seems reluctant to embrace it fully for reasons which have motivated philosophers from Malebranche until our own day: the purely causal, mechanical sensory processes on their own seem unable to explain the semantic, intentional aspects of meaningful experience.

'Dumb signs made in the brain'

Yolton cites Joseph Glanvill as among the very few writers who explicitly use the same notion of a reverse-sign relation to answer the question 'how the pure mind can receive information from that, which is not in the least like it self'.[12] Glanvill's characterisation of the problem is striking to modern readers through its precise anticipation of the notorious 'Chinese Room' conundrum of John Searle.[13] For Searle, the purely syntactic, causal processes of computational mechanisms are insufficient to explain the meaningful properties of mental representations. Computational symbols are like the meaningless squiggles of Chinese characters to an English speaker. Thus, Cudworth, too, is concerned precisely to explain how ideas arise from 'dumb Signs made in the Brain'.[14] Yolton reports Glanvill's question which echoes Searle's worry: 'But how it is, and by what Art doth the soul read that such an image or stroke in matter . . . signifies such an object?', since

> . . . without 'some unknown way of learning by them [the motions of the filaments of nerves] the quality of the Objects', the soul would be like an infant who hears sounds or sees lips move but has no understanding of what the sounds or movements signify, or like an illiterate person who sees letters but 'knows not what they mean'.[15]

Plus ça change . . . Yolton argues that Descartes offers his reverse-sign relations as a non-causal alternative to the usual semantic connection between ideas and their referents in the world:

> The stress on meaning in perception, especially the suggestion of motion being a natural sign for the mind, enables Descartes to replace the causal connection between felt experience and physical motion: motion in body does not cause but it signifies our sensations. Is there more to this distinction than just the convenience of a substitute relation for causation? Is there . . . an explication of natural signification?[16]

We see here that Yolton takes Descartes to be substituting the reverse-signification relation in place of the causal connection between motion and sensation. However, this appears to be a strained reading of the texts which would not independently suggest such a construal. It seems that Yolton shares the widespread discomfort with purely causal processes and seeks to supplement these with some additional mechanism. However, the texts cited by Yolton as evidence for a non-causal reading of the sign relation are most naturally interpreted as straightforwardly causal. Certainly Descartes' use of the word 'sign' to capture his notion is insufficient warrant for positing a semantic rather than a causal process. The connotations of the term are presumably wide enough to permit a purely mechanical, non-intentional conception. Indeed, in support of his account Yolton cites passages from the Sixth Meditation and *Les Passions de l'Âme* which both explicitly refer to causation.[17] Another passage cited from *Le Monde* is also taken by Yolton, following Alquié, to support a reverse-sign interpretation, but here Descartes speaks of the way in which words 'make us conceive of things', which is more plausibly taken as a causal claim than as a denial of it. Moreover, later in his chapter on the semantic relation, Yolton amply acknowledges that 'Descartes does frequently use the language of causation (produce, excite) when talking about some sensory awareness',[18] and he enumerates several examples from Descartes' texts. On Yolton's own evidence, then, it seems difficult to sustain his substitutional, non-causal attribution to Descartes. Indeed, Yolton can only support his account by ascribing a certain degree of inconsistency to Descartes,[19] but the need for such uncharitability in addition to the strained reading of the texts is perhaps a symptom of missing Descartes' point.

Moreover, these purely textual infelicities are likely to be a reflection of what is, on independent philosophical grounds, an unsatisfactory account of Descartes' intentions. Yolton's characterisation of Descartes' doctrine as an uprecedented and 'startling' one is perhaps another way of saying that it is intrinsically implausible as a solution to the problems in question. *Ceteris paribus*, we should prefer a less extraordinary account, unless it can be seen to have overwhelming, independent philosophical virtues. In the present case, however, the reverse-sign doctrine is, on Yolton's own admission, somewhat obscure and problematic. Clearly, it would be preferable if we could attribute to Descartes an insight which has philosophical merit as well as being textually more faithful. I suggest that such an exegetically elegant account is available once we see why the reverse-sign account should be so seductive yet misleading.

The 'obscure' and 'curious' doctrine: a closer look

In order to adjudicate the foregoing criticisms, let us consider more closely the passages from Descartes which are cited by Yolton in support of his non-causal, reverse-sign interpretation. Yolton[20] suggests that a particular passage in the Sixth Meditation is one 'where Descartes uses "sign" in this way' – namely in a reversal of the usual case, so that here 'the physical stimulus signifies the idea'. Yolton says that Descartes' suggestion of motion as a natural sign 'enables Descartes to replace the causal connection between felt experience and physical motion: motion in body does not cause but it signifies our sensations'. It is conceivable that, taken on its own out of context, Descartes' use of the term 'signal' might be construed to mean a sign in Yolton's reversed semantic sense, but the overall discussion in which this occurrence is found leaves little doubt about Descartes' meaning as ordinary causation. In the selected passage quoted by Yolton,[21] Descartes is speaking of the mechanisms by which the nerves convey information about pain from the limbs such as the foot:

> . . . when the nerves in the foot are set in motion in a violent and unusual manner, this motion, by way of the spinal cord, reaches the inner parts of the brain, and there gives the mind its signal for having a certain sensation, namely the sensation of a pain as occurring in the foot.[22]

This passage comes towards the end of an extended discussion of the manner in which the nerves conduct pain by movement exactly the same way that a piece of string can be pulled at one end to effect movement at the other. Just as in the case of a piece of string, movement of intermediate parts if pulled will have the same effect on the extremity. These passages preceding the one quoted by Yolton leave no doubt that Descartes is concerned with strict causes and effects in a perfectly ordinary sense:

> In a similar fashion, when I feel a pain in my foot, physiology tells me that this happens by means of nerves distributed throughout the foot, and that these nerves are like cords which go from the foot right up to the brain. When the nerves are pulled in the foot, they in turn pull on inner parts of the brain to which they are attached, and produce a

> certain motion in them; and nature has laid it down that this motion should produce in the mind a sensation of pain, as occurring in the foot.[23]

It is important to notice here that Descartes is concerned precisely with the doctrine of natural signs of interest to Yolton. The analogy of motion in the nerves with pulling on cords makes it clear that Descartes sees the signal in question as a cause whose effects are the sensations in question. The idea that when nerves are pulled 'they in turn pull on inner parts of the brain' is evidently a causal sequence of events and, accordingly, the 'signal' in the passage quoted by Yolton means the causal effect of motions in the nerves. Of course, Yolton acknowledges Descartes' commitment to the causal sequence of events, but argues that Descartes was also proposing an additional kind of relation. Thus, he says, 'there are two reactions operating in perception: the causal, physiological reaction and the signification reaction':

> What is important about this doctrine is the indication it gives of Descartes' effort to preserve an interaction between body and mind which is not causal, or which is more than causal. The two languages that he employs reinforce this suggestion: he recognized the causal relation between physical objects and the body, but he also recognized that that causal relation is inadequate for cognition. For the latter, a different, noncausal but still interactive relation is needed.[24]

On the contrary, however, it seems that Descartes can be understood as suggesting that the causal relation *is* adequate for cognition and constituted by it. Yolton explains further that 'the reaction to these signs is cognitive, not physiological, but it does work in tandem with the physical and physiological reactions'.[25] Thus, we see Yolton attempt to explicate what he concedes to be a 'curious' and 'somewhat obscure' doctrine, and one to which very little attention has been paid. Furthermore, Yolton, says 'I suspect it must be present in other writers as well, but so far I have not discovered other occurrences of it'.[26] Of course, these facts permit a different interpretation: the obscurity of the doctrine may be less due to Descartes than to Yolton. Relatedly, its absence in other writers and lack of scholarly attention may not be a failure to notice something, but rather due to its non-existence.

In support of his reverse-sign account, Yolton makes a further appeal to a passage from *Les Passions de l'Âme*, but this hardly supports Yolton's case any better than the texts we have seen, since it is also concerned with the mechanical workings of the nerves through spirits and pores. The very sentence quoted by Yolton is more naturally construed as offering a causal sequence in which, he says, the animal spirits enter certain pores in the brain and there excite 'a particular movement in this gland which is instituted by nature in order to cause the soul to be sensible of this passion'.[27]

Other crucial texts cited by Yolton include the *Dioptrique* and *L'Homme*, but these do not appear to support the reverse-sign interpretation on their own without contrivance. In *L'Homme*, Descartes' model is perhaps most notable precisely for the rigour with which it attempts to explain mental phenomena in terms of mechanical processes. Of course, his need to resort ultimately to a rational soul makes sense from an explanatory point of view, because of the limitations on such mechanisms to account for those special features of mind, such as language and knowledge, which rightly appeared to Descartes to transcend purely mechanical means. However, the joining of a rational soul to this machine does not appear to bear directly on the supposed reverse-sign relation which concerns only the ontological realm of *res extensa* prior to the final effects of the filaments and pores on the *res cogitans*. In *L'Homme*, then, we see an unproblematic causal sequence closely related to the other example cited by Yolton, and famously illustrated by the boy whose foot touches a fire. Here Descartes explains in precisely the same terms we have seen in the Sixth Meditation:

> Thus, if fire A is near foot B, the particles of this fire (which move very quickly, as you know) have force enough to displace the area of skin that they touch; and thus pulling the little thread *cc*, which you see to be attached there, they simultaneously open the entrance to the pore [or conduit] *de* where this thread terminates [in the brain]: just as, pulling on one end of a cord, one simultaneously rings a bell which hangs at the opposite end.[28]

Hume's problem: representations to understand themselves

There can be little doubt about the straightforwardly causal nature of the sequence which Descartes is postulating. The need to superimpose any additional significatory features appears to arise from extraneous theoretical preconceptions rather than from anything evident in Descartes' text. Specifically, it seems likely that the usual intentional connotations of the term 'sign' may induce us to read some representational meaning into Descartes' account, whereas I believe his concern is quite different. Undeniably, to speak of a sign may convey a notion of symbolic representation, but I believe that this is precisely the notion which is the source of the perennial difficulty which Yolton elsewhere actually does so much to clarify and dispel. The point is perhaps made most clearly by Dennett,[29] who drew attention to the difficulties for theories of mental representation in general. Dennett refers to it as Hume's Problem, which arises because 'nothing is intrinsically a representation of anything; something is a representation only for or to someone'. In attempting to understand

Yolton's analysis, it is revealing that he expresses his notion of signification in exactly these terms, saying of his reverse-sign relation that 'a sign stands for something else. It requires an interpreter; that is, a sign is a sign *of* something *for* someone.'[30] However, Dennett explains:

> Hume wisely shunned the notion of an inner self that would intelligently manipulate the ideas and impressions, but this left him with the necessity of getting the ideas to 'think for themselves' . . . Fodor's analogous problem is to get the internal representations to 'understand themselves'.[31]

Now, Yolton clearly acknowledges that physical motions in the brain do not have an interpreter in the usual sense, and recognizes Descartes' appreciation of this point, saying 'I think it incorrect to say that Descartes turned the mind into a quasi person or second perceiver'.[32] However, notwithstanding this acknowledgment, Yolton still maintains the appropriateness of such a significatory relation to explain Descartes' view, saying:

> Nevertheless, in these passages, Descartes is trying to assimilate physiological notions to natural signs, even though the signification relation in this case is not one of which we are aware. He is searching for an alternative to a causal relation.[33]

In this way, Yolton tries to have it both ways, that is, to have a semantic, significatory relation while, at the same time, denying the agent or interpreter for whom the sign serves to refer. This seems unsatisfactory on philosophical and exegetical grounds, which are both satisfied by dropping the attribution of non-causal, reverse-sign semantic relation in addition to the usual representational one. That is, Descartes is not searching for an *alternative* to a causal relation as Yolton suggests but, rather, he *identifies* the representational abilities of the mind with causal relations which are supposed to 'understand themselves'.

Although Yolton's reverse-sign relation takes the standard conception of signifier and signified as a paradigm, if we construe Descartes as appreciating 'Hume's Problem', then his talk of signs poses no difficulty or obscurity. Signification in this sense is precisely to be distinguished from representation because it does not carry the connotation of a user for whom the sign serves as a symbol. Descartes may be understood as proposing an account precisely of the kind Dennett suggests is needed. This reading of Descartes is strongly supported by the fact that his account of visual images in the *Dioptrique* is exactly of this sort: in this case, the images, so to speak, see themselves. It is in this sense that we are to understand Descartes' argument against resemblance: visual representations are not to be conceived on the model of our external pictures which resemble their referent, since this would require that they be seen by someone. Instead, it is sufficient if the images encode the relevant information about the physical objects. My suggestion is that it is such a notion of encoding which best captures Descartes' concept of the sign relation. There are ample texts, including especially *L'Homme* and *Dioptrique*, in which it is clear that Descartes' account of visual perception involves the transmission of such signals along the nerves from the retina to the brain in what is essentially a correct account of the encoding of information in the modern sense.[34] Of course, this is a sense in which the encodings are intrinsically meaningless, hence, giving rise to the philosophical anxieties which have preoccupied philosophers from Descartes' time to our own, as Yolton has shown. The dilemma is that, if the representations are meaningful, then they appear to intervene between the mind and the world precluding a direct realism, whereas if they are meaningless they appear unable to do the job. Since Yolton takes Descartes to be seeking a direct realism, it makes sense that Descartes should avoid the triadic schema which entails meaningful intermediary entities, just as Yolton's Arnauldian account itself suggests.

To help clarify Descartes' surprising and puzzling conception, Yolton suggests that Descartes appears to distinguish signifying from representing.[35] A few pages later, however, he avers that 'perhaps the distinction between signifying and representing is not entirely clear', and may perhaps be best understood in terms of the two directions in which the relation between object and its symbol may be connected, telling us that if 'there is a difference, perhaps we can say that the signifying relation replaces the causal relation between physical motion and ideas, but the representing relation goes, as it were, outward from awareness'.[36]

Yolton's analysis here is illuminating, though inevitably retaining an air of paradox, as he concedes in occasional *obiter dicta*. Thus, as we have seen, he says that the distinction between signifying and representing remains unclear and that 'This significatory relation is somewhat obscure in Descartes' brief use of it'.[37] These remarks suggest that on Yolton's own account Descartes' doctrine remains somewhat puzzling.

A second, non-mechanistic, non-naturalistic relation?

Yolton cites Gaukroger's recent discussion of these matters in support of his own account. Here Gaukroger contrasts Descartes' account in *Le Monde* with that of the *Regulae*, saying that in *Le Monde* Descartes offers a significantly different story. Specifically in *Le Monde*,

> Perceptual cognition is not thought of in causal terms, and it is not thought of as a multi-stage process. Rather, the treatment focuses on the question of how we are able to respond to certain properties or events as information.[38]

Gaukroger suggests that in *Le Monde* Descartes proposes

> . . . that we conceive of visual cognition not in terms of the mechanical-causal process involved in perception, but as a single unified act of comprehension. . . . We are now presented with a completely different non-pictorial type of model, a linguistic one.[39]

There is room for considerable uncertainty about Descartes' intentions in what Yolton describes as 'those cryptic sign passages'[40] but, acknowledging the differences to which Gaukroger draws attention, there is a danger of overstating the extent to which Descartes is concerned with two different, though related, processes. Thus, Yolton refers to Margaret Wilson's emphasis on the 'linguistic' model as Descartes' analogy for dismissing resemblance accounts of perception in favour of encoded signals, but he downplays the importance of this, saying

> That may be one of the features of Descartes' suggestion of brain motions as signs to the mind, but I would think that the more important aspect of those passages on natural signs is their use as a means of suggesting a second, nonmechanistic, interaction between brain and mind.[41]

However, I believe that there are strong grounds for seeing this latter issue, not as a different, contrasting doctrine, but as the very same one to which Wilson refers. Above all, Descartes is not articulating a 'second, nonmechanistic interaction', but explaining what the brain motions as natural signs *are*. Yolton cites Wilson's own remarks to this effect, but seems to conclude that Descartes was, after all, concerned to offer a 'second kind of interactive relation, not just conjunction, parallelism, or occasionalism'.[42] Of course, the alternative to Yolton's interpretation need not be any one of these, but rather an identity claim: the causal-mechanical processes are to be seen as *identical* with the semantic one. However, it is significant that, in answer to Wilson, Yolton appeals to writers who take a somewhat extreme and implausible non-naturalistic, metaphysical position, according to which Yolton says 'what science cannot do is to explain how bodily states and processes become experiences'.[43] Yolton appears to endorse the view of these authors who suggest that we must take 'semantic presence as a basic category, just as existence is a basic category'.[44] Yolton invokes the ideas of J.S. Kelly and E.M. Adams 'not because they speak directly to issues in Descartes, but because they make use of concepts very similar to those employed by Descartes'.[45] Yolton acknowledges that the views in question take the semantic relation to be 'nonnatural' and transcending what is scientifically explicable. However, in view of Descartes' thorough-going, strenuous naturalism, this seems to be a desperate move, and the doctrines are unlikely candidates for views which are 'very similar to those employed by Descartes'. It must be acknowledged that the issues at stake are profoundly difficult and recalcitrant – and still the subject of considerable perplexity. However, the persistent intractability of the problem is not exegetically relevant or favourable to a reconstruction of Descartes in terms of such occult notions as 'semantic presence as a basic category'.

Thus, Yolton rejects identifying the mechanical-causal processes with the significatory relation in favour of two independent functions:

> I have been suggesting that brain motions play two roles, one responding to physical motions coming from the environment, the other triggering conscious reactions in perceivers.[46]

Significantly, however, Yolton concedes the obscurity of the analysis, admitting that his account leaves Descartes' doctrine somewhat opaque:

> This latter role *is* far from clear, and its intelligibility *is* in doubt, but its importance lies in its suggestion of two interacting relations between perceivers and external objects.[47]

Yolton cites Gaukroger's analysis of Descartes' doctrine of signs in support of his own account, drawing attention to Gaukroger's emphasis on the distinction between causal and semantic aspects of Descartes' doctrine. Yolton does record Gaukroger's concern to 'resist saying that there are two processes', but nevertheless emphasises his analysis of *Le Monde* and the *differences* between this and the *Regulae* account of causes. To be sure, in *Le Monde* Descartes does not explicitly speak of sequential causal mechanisms, as he does elsewhere when describing the effects of bodily movements through the fibres, etc. However, it does not follow from this absence that Descartes is making a contrast with the causal account. The absence of any causal explanation may be explained in an obvious way – namely, that Descartes is concerned with a significantly different point – explaining why resemblance is neither necessary nor sufficient for representation. It is perhaps to overstate this to describe it as invoking a 'linguistic' model rather than a pictorial model, as Gaukroger does. After all, in the case of visual perception Descartes' point is to *deny* the relevance of pictorial representations and, therefore, cannot be said to be appealing to a pictorial model. In this sense, Gaukroger's wording of the contrast between *Le Monde* and *Regulae* may encourage Yolton's reading of a divergence in Descartes, but Gaukroger only contrasts the specific concerns of the texts in question and does not endorse Yolton's view of a dual process:

> First, when he offers an account of what we might call sensory stimulation and perceptual understanding, he is not offering an account of

> two separate processes, but an account of a single act which can be characterized in two ways, in terms of a causal-mechanical process and a significatory process.[48]

In the end, ironically, it seems that Yolton embraces a dual-process account precisely because he wishes to avoid the implication of an intelligent or conscious 'code reader', which he takes to be a consequence of brain motions giving rise to perceptual recognition.

> Certainly, our normal use of signs is in the context of conscious interpretation of the signs, but it does not seem to me that that is what Descartes was suggesting. Therein, of course, lies the difficulty of making sense of Descartes' notion of the mind reacting to brain motions as signs. To read the signs or codes presented by the brain would seem to require the mind to scan the motions in the brain.[49]

Yolton's position here appears paradoxical and a little difficult to understand. He seems to reject a conception of 'the brain presenting certain motions for the mind's attention' because of the implication of a code-reading homunculus. However, he avoids this notorious difficulty by resorting to the dual-process account rather than the obvious alternative – namely, a unitary, formal, causal-mechanical one. That is, Yolton appears to think that his semantic account does not fall victim to the familiar explanatory regress, despite admittedly invoking precisely the kind of semantic relation which leads to the problem. He says: 'I do not find it obvious that the few passages suggesting that the mind reacts to brain motions as signs is the same as the brain *presenting* certain motions for the mind's attention.'[50]

In this respect there is an ambivalence in Yolton's position, since he clearly recognizes the need to avoid the interpreting homunculus but, at the same time, embraces a semantic relation which invites it. Yolton concedes that his resolution of this tension by positing dual roles for brain motions is unsatisfactory:

> This latter [significatory] role *is* far from clear, and its intelligibility *is* in doubt, but its importance lies in its suggestion of two interacting relations between perceivers and external objects.[51]

Of course, the question is whether these doubts about the clarity and intelligibility of the doctrine are to be blamed on Descartes' doctrine as such, or on the reverse-sign reconstruction of it.

The puzzle of meaning for mental representations is undeniably a real one and, indeed, remains notoriously unclear to this day. The interest and importance of Descartes' writing on the subject is to be seen in its offering a solution to the vexed question which is as relevant today as in his own time. However, the persistence of the issue is sufficient indication of a recalcitrance which will guarantee that his solution will be discerned through the spectacles of the dominant conceptions. The debate about Searle's Chinese Room and, more broadly, Fodor's 'formality condition', with its 'methodological solipsism', is testimony to the counter-intuitiveness of a certain reductive view of meaning and the difficulty of seeing how purely formal, causal mechanisms can suffice to explain intentionality. Nonetheless, right or wrong, the textual evidence suggests that Descartes is to be classed among those who advocate such a syntactic, mechanical, geometrical and purely formal account of mental representation. The point of the oft-quoted passages from *Le Monde* and the *Dioptrique* is to argue that once resemblance is abandoned as the basis for representation, anything which functions to convey the appropriate information about the physical world suffices to constitute the semantic relation between ideas and their referents. Given such a functional conception, there is no need to suppose Descartes to have substituted a secondary, novel semantic relation for the causal link between brain motions and ideas, since the brain motions are supposed to *constitute* the ordinary representational relation via their abstract encoding of information. Thus, despite offering the most important clarifications of these questions, Yolton himself seems to be to some extent under the influence of certain problematic assumptions. If it were not for these, there would appear to be little incentive to read Descartes as offering anything other than a straightforward causal story about the origins of sensation in the bodily movements of filaments, pores and animal spirits. That these are not thought to suffice as explanations of conscious experience is a reflection of the deep-seated difficulty which continues to plague the subject.[52]

Notes

1 J.W. Yolton, *Perception and Reality: A History from Descartes to Kant* (Ithaca, 1996), 73.
2 Ibid, 190.
3 Ibid,196.
4 Ibid, 186.
5 Quoted in ibid., 186.
6 'The Background to the Problem of Perceptual Cognition', Introduction to A. Arnauld, *On True and False Ideas*, ed. and trans. Stephen Gaukroger (Manchester, 1990).
7 In two crucial passages from Descartes, Gaukroger's quotation is slightly in error altering, indeed, reversing, the meaning of Descartes' point. From Rule 12, the analogy between information in the nervous system and the movements of a pen whose tip traces out motion in the air omits the word "but" and should read '. . . the slightest motion of this part cannot *but* be traced out in the air by the tip of the quill, even though I do not conceive of anything real passing from one end to the other' (ibid., 17). The second passage concerns the analogy of natural signs with laughter and tears, in which the order of the first two words is reversed and the final question mark is omitted, turning the

sentence into a negative assertion rather than a rhetorical question having precisely the opposite meaning. Rather than reading 'It is not . . .', Descartes' sentence should read 'Is it not thus that nature has established laughter and tears, to make us read joy and sadness on the faces of men?' (ibid., 24).

8 Ibid., 24.
9 Yolton, op. cit. 190.
10 Ibid., 190.
11 Ibid., 190.
12 Ibid., 191.
13 J. Searle, 'Minds, Brains and Programs, *Behavioral and Brain Sciences* vol. 3 (1980), 417–24.
14 Yolton, op. cit., 192.
15 Ibid., 191.
16 Ibid., 187.
17 Ibid., 187.
18 Ibid., 202.
19 Ibid., 203.
20 Ibid., 187.
21 Ibid., 187.
22 AT vii. 88.
23 AT vii. 87.
24 Yolton, op. cit., 73–4.
25 Ibid., 73.
26 Ibid., 73.
27 Ibid., 187.
28 AT x. 141–2.
29 D.C. Dennett, 'Artificial intelligence as philosophy and as psychology', in *Brainstorms* (Vermont, 1978), 109–26.
30 Yolton, op. cit., 208.
31 Dennett, op. cit., 101.
32 Yolton, op. cit., 209.
33 Ibid., 209.
34 In this regard, it is difficult to see why Ann Wilbur MacKenzie, whose account is generously praised by Yolton, should write disparagingly of Descartes' speculations about the mechanisms of sensory perception. She describes these speculations about sensory processes as 'often quite uncontrolled' and adds 'Particularly uncontrolled are his speculations about neuromechanics' ('Descartes on life and sense', *Canadian Journal of Philosophy*, vol. 19 (1989), 163–92: 163). On the contrary, Descartes' speculations are not only correct but an insightful solution to the problem of imagery which precisely anticipates recent responses to pictorial theories of visual images in psychology: see P. Slezak, 'The "Philosophical" Case Against Visual Imagery', in P. Slezak, T. Caelli and R. Clark, eds., *Perspectives on Cognitive Science*, (Norwood, 1995), 237–71.
35 Yolton, op. cit., 186.
36 Ibid., 190.
37 Ibid., 73.
38 S. Gaukroger, *Descartes: An Intellectual Biography* (Oxford, 1995), 282.
39 Ibid., 283.
40 Yolton, op. cit., 199.
41 Ibid., 198.
42 Ibid., 199.
43 Ibid., 200, 218 n.
44 Ibid., 200.

45 Ibid., 199.
46 Ibid., 198.
47 Ibid., 198.
48 Gaukroger, op. cit., 287.
49 Yolton, op. cit., 198.
50 Ibid., 198.
51 Ibid., 198.
52 The extensive contemporary literature attests to a consensus at least on Fodor's judgement that 'of the semanticity of mental representations we have, as things now stand, no adequate account': J.A. Fodor, 'Presentation to National Science Foundation Workshop on Information and Representation', in B.H. Partee, S. Peters and R. Thomason, eds., *Report of Workshop on Information and Representation* (Washington, D.C., 1985), 106–17.

22c The role of inner objects in perception

Celia Wolf-Devine

One of the things which motivated me to write *Descartes on Seeing*[1] was a desire get at the source of the idea that in perception we are directly or immediately aware of some sort of inner object that mediates between the knower and the known. I argued there that one of the roots of this view lay in Descartes' theory of vision – specifically, in his understanding of the role of the retinal image in vision. Yolton is also concerned with this problem, and wishes to show that Descartes (and most of the other major early modern philosophers, with the exception of Malebranche) did not really hold the sort of representative theory of ideas which has often been attributed to them, and thus are not vulnerable to 'veil of perception' scepticism. While I am sympathetic to his desire to avoid both veil of perception scepticism and a merely physicalistic account of perception that leaves out the reality of perceptual awareness,[2] I am not fully persuaded that the account Yolton develops should be characterised as Descartes' 'mature view'.[3] And furthermore I have some doubts about how coherent the view is in its own right.

Part of what is at issue between us is, I think, a methodological difference about the value of certain sorts of rational reconstruction. Descartes' views evolved in the course of his wrestling with different questions in the context of dialogue with very different sorts of opponents. Not only does Descartes use different terminology when addressing different opponents, and address different questions in different texts, but his views also develop through a sort of internal dialectic as he comes to acknowledge implications latent in his earlier views. The question, then, is how the historian of philosophy should handle the resulting tensions and apparent inconsistencies. Yolton recognizes that it is difficult to discover a systematic account of perceptual cognition in Descartes, and takes it to be his task to extract or construct a coherent theory out of materials drawn from various texts, admitting that the one he constructs is 'a bit obscure and not fully developed' in Descartes.[4]

I have reservations about this sort of rational reconstruction. For, although we should of course try to harmonize the various things Descartes says about perception, we should be careful to be faithful to the texts and not force a fit between them. For example, as I argued in *Descartes on Seeing*, Descartes' discussion of the role of sensation and judgment in perception in the Sixth Replies (which occurs in the context of a dispute over the reliability of the senses relative to that of the intellect) differs quite significantly from his account in the *Dioptrique* (a work in which he was concerned less with issues of certainty than with showing that the perceptions of the senses could be successfully explained without recourse to the forms or real qualities postulated by the scholastic philosophers). And I am inclined to think that the language of formal and objective reality in the Third Meditation cannot easily be grafted into his more scientific discussions of perception in *La Dioptrique* and *Le Monde,* as Yolton tries to do.

Methodologically, I prefer the approach taken by Margaret Wilson.[5] When she discovers tensions between various texts, she does not try to force them to harmonise or to label one of them as his real view and discard the others, but painstakingly examines the terminology Descartes uses to speak about the relation between motions in the brain and our sensations in a wide variety of different contexts, and sketches the several alternative models for understanding the relation between motions in the brain and our sensory ideas that seem to underlie his terminology. Whether or not they can be harmonised is a question she takes up after she has explored each one carefully, and if at some points they cannot be harmonised, she simply acknowledges this fact. Although her method admittedly leaves us with 'loose ends', it has the advantage of keeping us close to the texts and enabling us to get a better feeling for how Descartes himself was thinking in various contexts and why.

Yolton's view, which he attributes to Descartes, is that there is no causal connection between the motions in our brains and our perceptual experience. Instead, he argues that there are two interactive relations occurring between perceivers and the physical world: a physical causal one which holds between objects and our nervous systems and brains, and a cognitive or 'semantic' one which involves the mind responding to what is happening in the nerves and brain.[6] He says that 'this response is not caused by physical events; rather physical events are interpreted by the mind'[7]; 'ideas are the mind's significatory responses to the natural signs of physical motions in nerves and brain'.[8] Or, as he put it in his earlier book, 'ideas are not causal effects of motion but semantic and epistemic responses to it'.[9] Since Yolton does not claim that this view is the *only* account of perception present in Descartes' writings, discordant texts do not necessarily rule out his interpretation, and this makes the task of evaluating it difficult. But the main problems for his interpretation seem to lie in two areas: (1) in his claim that the connection between motions in the brain and our sensations is *not* a causal one, and (2) in articulating clearly the alternative that he is proposing.

(1) Descartes often uses causal or implicitly causal language in talking

about the relation between motions in our brains and our sensations. Wilson cites a wide variety of texts in which causal, or implicitly causal, language is employed in discussing the relation between motions in the brain and our sensations.[10] She also argues at length that the heterogeneity of mental and physical substance does not, according to Descartes,[11] preclude causal interaction between them. If, then, Yolton wishes to maintain the radical view that there is *no* causal action of brain motions upon the mind, it is incumbent on him to provide better textual evidence than he does that this was Descartes' mature and considered view. Yolton may be unhappy with the causal locution, but was Descartes unhappy with it?[12] And if so, was he unhappy for the same reasons Yolton is or for other reasons?

In his defence, of course, Yolton can document the presence in Descartes' writings of other locutions for speaking about the relation between motions in the brain and our sensations, and point out (correctly, I think) that this shows Descartes was not locked into a single way of thinking about the relation between motions in the brain and sensations.[13] He sometimes speaks of the brain as presenting a pattern of motions to the mind. He also speaks of the motions in the brain 'giving occasion to the soul' to 'form' or 'conceive' certain ideas of sense,[14] and in yet other contexts he employs the language analogy according to which the motions serve as signs which are instituted by nature to make us have certain sensations.[15] Wilson, however, argues that none of these locutions are inconsistent with the existence of a causal connection between motions in our brains and our minds. For, how could something serve as a sign to the mind, for example, unless it effected some sort of change in it?[16]

In his response to Wilson, Yolton asks whether the causal process occurring between objects and the motions in our brain (which involves physical motion and impact) is of the same sort as that which occurs in brain-to-mind causation. If we say it is the same, then this tends to materialise the mind. If we say that the two causal relationships involve different sorts of processes, then we have 'two causal relations, two interactive relations'.[17] Wilson concedes that Descartes did not regard body–mind causation as a case of causation by physical motion and impact,[18] but what follows from this? Yolton at this point interprets Wilson's admission that body–mind causation is not a case of causation by physical impact, as an admission that there is another kind of non-impact causation[19] (which seems fair enough), but then slides quickly back into his own preferred locution about two kinds of 'interactive relations', with the word 'causal' having been dropped. But it is one thing to say that the way brain motions affect the mind is not a case of causation by impact, and quite another to say that it is not a case of causation at all. Is he denying all causal connection between brain and mind, or merely making the far less controversial claim that this sort of causation is of a different sort from that which obtains between physical things?

Perhaps he does not, after all, really mean to deny that brain motions cause sensations. He says things that sound quite radical, speaking of 'Descartes' rejection of any causal relation between the physical activity of objects on our sense and the perceptual ideas in our minds'.[20] But there are passages in which he seems to retreat from this, saying things like 'unless we can explicate the causation of the significatory response, we *may* want to limit the causal relation to the perceiver's body'.[21] And in another place he says '*perhaps* we can say that the *signifying* relation replaces the causal relation between physical motions and ideas'.[22]

It is extremely difficult to sort out the issues here because the key terms 'causal' and 'interaction' are very ill defined. Sometimes Yolton seems to use them interchangeably,[23] but more often he contrasts object–brain interaction and brain–mind interaction, calling the former a causal relation and the latter a 'semantic' or 'significatory' relation. Carving out a space for some way of understanding the relation between brain and mind in sensation that is not merely causal seems to me to be very close to the heart of Yolton's whole project; if I am correct about this, he needs to be more forthcoming about what he means by a 'causal relationship' and why he finds it so objectionable to speak about motions in the brain causing our sensory ideas.[24] The terms 'cause' and 'causal' are notoriously capacious ones,[25] and clarification is required.

The term *inter*action would seem to imply that the two things act upon each other. But causation need not involve a two-way interaction. The sun, by shining on it, causes a rock to grow warm, but the rock has no effect on the sun. Nor do the changes in my eyes and brain caused by the light coming from some object have any effect on that object. And cases of perceptual recognition do not seem correctly describable as cases of interaction either – or at least not interaction with the object perceived. I look out of my window, see an eagle flying by, and exclaim 'Hey, there goes an eagle!' Unless the eagle hears or sees me, I have no effect on it. Perhaps the sort of significatory or semantic relation which he postulates to hold between brain motions and the mind can be more accurately described as a case of genuine two-way interaction, but I am unclear how.

(2) Supposing we concede for the sake of argument that the relationship between brain motions and our sensory ideas is not a causal one, how are we to understand the alternative proposed by Yolton? The main text on which Yolton relies in developing his natural sign theory is the notoriously difficult first chapter of *Le Monde*. Perceiving is like grasping the signification of spoken words. Words have meaning only by human convention, but there are also what Descartes calls 'natural signs' – for example, tears and smiles are natural signs of sadness and joy. Descartes says:

> But if words which signify nothing except by human institution, suffice to make us think of things, with which they have no resemb-

lance: why cannot Nature have also established a certain sign, which makes us have the sensation of light although this sign has nothing in itself which is similar to this sensation? And is it not thus that she has established laughter and tears to make us read joy and sadness on the the faces of men? You will say, perhaps, that our ears only really make us sense the sound of the words and our eyes only make us sense the face of the one who laughs or cries, and that it is our mind which having retained that which the words or countenance signify, represents it to us at the same time. To this I can respond that it is our mind, that in the same way, represents to us the idea of light, each time that the action which signifies *it* touches our eye [*c'est notre esprit toute de meme, qui nous represent l'idee de la lumiere, toutes les fois que l'action qui la signifie touche notre oeil*].[26]

According to Yolton, then, Descartes in this passage is saying that the mind when perceiving light 'reads the physical motions [in the brain], as it does the tears and smiles of a face'.[27] The brain motions are the signs, and our sensations are what is signified. He calls this the 'inverse sign' relationship.[28] Obviously, the case of perceiving light differs from the case of perceiving joy or sadness by the smile or tears we perceive on the other's face, since we are not and cannot be aware of the motions in our brain as we are of the sound of the words or the expression on our friend's face. Thus, Yolton explains, the perceiver 'reacts unconsciously' to motions in his brain by forming ideas,[29] and the mind is able to do this because it is 'so created by God that it has the semantic reaction of sense and idea'.[30] Yolton believes we can understand the sign relation and the semantic interaction to occur unconsciously without thereby introducing a homunculus who is doing the interpreting. Current writers would, he says, describe it as occurring at a preconscious or subpersonal level; the mind just has a natural function of reacting in this way to brain motions.[31]

I am troubled by a number of features of his interpretation here. First, the 'inverse-sign' relationship is baffling. It does seem counter-intuitive, as Yolton himself notes.[32] One would naturally expect that the motions in our brains function as signs of things out there in the world, but Descartes seems to be saying that the physical motions signify to us the sensation we feel. But regarding the motions in our brain as signs of (or for) sensations seems inconsistent with the outward-directed and intentional nature of perceptual consciousness.[33] Perhaps there are two senses of 'sign' at work here. A sign may be an indication of the presence of something (as smoke is a sign of fire). It may also be a signal to someone to do something – as the firing of a gun is a sign to the runners to begin a race. And perhaps it is in the latter sense that brain motions may be signs to the mind to form ideas. This interpretation is not without difficulties as we shall see below, but at least it makes more sense than the referent of the signs being a sensation in my own mind.

On my reading, however, there is a certain amount of ambiguity in the texts, and I don't think that Yolton's reading of the 'inverse-sign' relationship is forced on us. The referent of the pronoun 'it' ('*la*' in French) in the last sentence in the above quotation from *Le Monde* could be, I think, either the idea (as Yolton reads it) or the light, since both '*idée*' and '*lumière*' are feminine. And the next sentence after the one quoted would seem to support the interpretation that it is light ('*la lumière*') rather than our idea ('*l'idée*') that is the referent of '*la*'. It reads: 'And is it not thus that she [nature] has established laughter and tears, to make us read joy and sadness on the face of men?'[34] For surely the joy and sadness we read on the face of men is not a sensation in our minds, but the joy or sadness they are feeling. Since the cases are said to be parallel, an external referent in the last sentence would support a choice of the external referent (light) in the preceding sentence also.

Second, regardless of what the motions in our brains are signs *of* or *for*, there are serious difficulties with the claim that something of which the mind is not aware can serve as a sign for it. Yolton speaks of the mind 'responding' to the brain motions, says the physical motions 'are interpreted by the mind', and describes the mind as 'reading the physical motions, as it does the tears and smiles of a face'.[35] Some very deep philosophical problems lurk just below the surface here. To what extent is it legitimate to speak of my mind doing things of which I am not and cannot possibly be aware? Does doing this not introduce some sort of homunculus? Does Descartes successfully avoid a homunculus, and is Yolton able to do so?

In *Descartes on Seeing*, I argued that since the basic mechanism of vision according to Descartes involves a point-to-point projection of the pattern of motions produced on the retina to the cerebral cavities, and ultimately to the pineal gland (the images from the two eyes being merged), he needs to postulate some sort of corrective mechanisms in order to explain why we do not see things as they are represented in the retinal image, and that at least some of the corrective judgments he hypothesises do commit him to a homunculus in spite of himself.[36]

Whether Yolton's version of the natural sign theory can escape postulating a homunculus is not clear. It depends on how we understand what is occurring when the mind is said to be 'interpreting' or 'reading' the physical motions. One way of reading this is what Wilson calls the presentation model, in which the brain presents something (a pattern of motions) to the mind. She points out (correctly I believe) how very pervasive this model is in Descartes' writings, and argues that one cannot easily dismiss it as merely metaphorical. Yolton actually seems willing to allow his use of the term 'interpreting' to be understood along these lines. He says: '. . . physical events are interpreted by the mind. Descartes has this interpretation in mind when he speaks of the mind attending to or studying the figures on the pineal gland.'[37] But this latter passage seems very clearly to involve a homunculus; interpreting and reading are things people do, and this is even more evidently true of attending to or studying. And if he does postulate a homunculus who inspects the patterns of excitation in the brain and reads or interprets them, then the task of this homunculus will obviously an impossible one.[38] Even the more intuitively plausible variant of the homunculus that Descartes introduced to explain distance, size, and shape perception would have to perform highly complex calculations with lightning speed, and this led Malebranche in *Eclaircissment XVII*[39] to conclude that no finite intelligence could do this and that therefore it is God who causes our perceptual ideas.

Yolton believes that he can avoid postulating a homunculus. For, on his view, the sign relation and the semantic interaction occur unconsciously, and he thinks that various contemporary theorists, who talk of things like subpersonal processing at a preconscious level, are or will be able to explain what is going on in a way that avoids postulating a homunculus. I do not think this will work, and have doubts generally about attempts to pull a cognitive rabbit out of a material hat[40] in this sort of way, but cannot go into this issue here.

Third, it is not at all clear that Descartes in the first chapter of *Le Monde* really means to deny a causal relationship between the motions of the light particles or motions in our brain and our sensation of light, and if he does not do so in this passage, which is the primary source of the natural signs theory, then this does tend to seriously undermine any claim that he denied brain to mind causality. In the first paragraph of the chapter he said that he is trying to get us to realise that there may be a difference between the sensation we have of light and what it is in the objects that 'produces (*produit*)' this sensation within us. He also speaks of nature having established a sign 'which makes us have the sensation of light (*que nous fasse avoir le sentiment de la lumière*). Both 'producing' and 'making us have a sensation' sound like there is a causal relationship involved, and thus the most natural reading of this chapter of *Le Monde* would seem to be that Descartes is merely cautioning us against supposing that there must be a similarity between the idea and its cause – not denying the existence of a causal relationship entirely.[41] In fact, Yolton himself seems to concede this point, for immediately after his discussion of the natural signs theory in *Le Monde*, he cites several passages where he says that Descartes uses the term 'sign' in the same way as he did in *Le Monde*. But both of them are cases where Descartes explicitly uses the term 'cause' to describe the relation between motions in the brain and sensations in the soul, noting that this occurs as a result of the institution of nature.

Fourth, if the causal locution proves so pervasive and closely intertwined with everything else, including even the natural signs locution, it would seem we cannot make the attractively simple move of saying that there is a causal interaction between object and brain and a semantic or significatory interaction between brain and mind, and that these two processes are entirely distinct from each other. How then are the causal and the semantic interactions connected with each other? Are we perhaps dealing with two different (perhaps complementary) languages for describing the same process? Stephen Gaukroger criticises Yolton for tending to treat the causal-mechanical process and the significatory process as independent in *Perceptual Acquaintance*.[42] In *Perception and Reality*, Yolton tries to explain their connection further, saying:

> The causal and significatory relations are linked. They have as their vehicle one and the same process, a physical process. When that process disturbs sense organs and brain, there is a causal rooting in the physical world. The disturbance of the brain becomes a sign for the sentient organism whose reaction, a sensation, is what that sign *signifies*.[43]

He also speaks of causal language and noncausal language and cites the natural signs doctrine in *Le Monde* as an example of a noncausal language for discussing what occurs in perception, but on the next page says Descartes is trying to 'preserve an interaction between body and mind which is not causal, *or which is more than causal*'.[44] But saying a relation is noncausal and saying it is also something more in addition to being causal are very different. Is Yolton merely insisting that, yes, more is going on in perception than just bodies bumping up against each other and the physical changes that occur in them as a result – that in fact cognition, meaning, and perceptual awareness somehow emerge from this process? If this is all he is saying, then I am not sure who he takes himself to be arguing against.

And if Yolton does in fact want to *replace* the causal locution for talking about the connection between the brain and the mind with the natural signs locution, what, exactly, turns on whether we say that motions in our brain cause certain sensations as a result of the 'institution of nature', and saying that our sensations or perceptual ideas are the mind's significatory response to the motions occurring in the brain (a capacity which it just naturally has). Something very much like Descartes' 'institution of nature' must be invoked in both cases. Granted, the mind might *seem* to be more active if we speak of it as responding or reacting to motions in the brain, but the sense in which it is active is extremely unclear.

Finally, using the language analogy to elucidate the connection between brain motions and the mind in perception really does not go very far toward enabling us to understand what is actually going on. He cannot possibly be saying that the mind inspects the patterns of excitation in the brain and reads or interprets them. This cannot be done without introducing a homunculus, and if a homunculus is introduced here it is immediately obvious that its task would be an impossible one. So just what one is asserting in saying that brain motions serve as natural signs is quite unclear.

Harry Bracken, in his review of *Perceptual Acquaintance* puts the point quite well. He says:

> I have always assumed that the *semantic* talk in these Cartesian philosophers was meant to indicate that the relation involved was *sui generis,* and that it was neither necessary nor causal nor 'resembling'. . . . One appeals to the 'semantic' story not because one knows how language is 'about' the world but precisely because one does not. . . . With respect to translating ontology into semantics, it can only advance our understanding if we know how natural languages . . . are about the world.[45]

When struggling to articulate how the semantic or significatory interaction works, Yolton sometimes says the natural signs (motions in the brain) 'trigger' specific sensations and ideas.[46] But this is mere metaphor, as he himself acknowledges. He says:

> I have been suggesting that brain motions play two roles, one responding to physical motions coming from the environment, the other triggering conscious reactions in perceivers. This latter role *is* far from clear, and its intelligibility *is* in doubt, but its importance lies in its suggestion of two interacting relations between perceivers and external objects.[47]

A similar sort of tentativeness occurs in his response to MacKenzie.[48] He says: 'When brain states mean something to the mind, some interactive process occurs. It *may* [italics added] be no more illuminating to speak of *meaning* than to speak of *causing* in such a context, but we need to recognize the kind difference between causing and meaning.'

That Yolton has difficulty articulating clearly just how perception works is not to be wondered at. There is something unique about perception, and I am inclined to think that neither the analogy with our capacity to understand a language, nor the analogy with the sort of causality at work between physical objects, is a very good one. I am reminded of Judith Thomson's famous analogy between an unwanted pregnancy, and being kidnapped and hooked up to an unconscious violinist. Nothing can be really analogous to pregnancy, as it is that process through which life comes to be. And perception, likewise, is the root or source of all our knowledge; it is that process through which the world comes to be for me. Everything else presupposes it.[49] We cannot somehow get underneath perception or behind it to discover how our perceptual knowledge is grounded.[50] Science may try to, but scientists must rely on their senses; a scientific account of perception presupposes our ability to identify and measure things. An outside person can discover certain correlations between patterns of excitement in the brain and perceptual awareness, but this does not tell us what causal or significatory relationships hold between them.

No matter how we talk about brain motions 'triggering', or 'causing' sensations, there is a level of brute fact that resists further explanation. And I am not at all sure, when one gets down to this level, that it makes any difference at all whether we say that certain motions in the brain cause certain ideas because that is the way our minds and bodies are joined, or whether we say that the mind has a natural function of reacting to brain motions as signs. In either case, our having certain sensations when certain motions occur in our brains is simply a brute fact resting on something very like Descartes' institution of Nature.

Questions about perception easily give rise to theological questions, and indeed during the early modern period these usually lie quite close to the surface. The 'institution of Nature' in Descartes is, of course, rooted in God's choice to join our minds to our bodies in such a way that we have certain sensations when certain motions occur in our brains (which, being good, he did in such a way as to be conducive to the well-being of the soul–body composite), so for him there is good reason to trust capacities we have by the institution of Nature. But as Thomas Reid puts it, 'he who is persuaded that he is the workmanship of God, and that it is a part of his constitution to believe his senses, may think that a good reason to confirm his belief [in the evidence of his senses]', but 'a man would believe his senses though he had no notion of a deity'.[51] Yolton eschews explicit consideration of both metaphysics and theology, but I am not at all sure that his analysis gains in clarity from doing so.

Notes

1 *Descartes on Seeing: Epistemology and Visual Perception* (Carbondale, 1993).
2 At least, this is how I read his remarks in J.W. Yolton, *Perception and Reality: A History from Descartes to Kant* (Ithaca, 1996), 15.
3 J.W. Yolton, *Perceptual Acquaintance* (Oxford, 1984), 19.
4 Ibid., 19.
5 Margaret Wilson, 'Descartes on the origin of sensation', *Philosophical Topics* vol. 19 (1991).
6 *Perceptual Acquaintance*, 30.
7 Ibid., 30.
8 *Perception and Reality*, 12–13.
9 *Perceptual Acquaintance*, 19.
10 A particularly clear instance of this occurs in his well known letter to Princess Elizabeth in which he speaks of the body acting upon ['*agir sur*'] the soul ['*l'âme*'], in 'causing its sensations and passions' ['*en causant ses sentiments et ses passions*']. AT iii. 665.
11 She cites in support of this a letter to Clerselier in which Descartes essentially comes out and says that just because the soul and body have different natures, this does not prevent them from being able to act the one upon the other. AT ix-B. 213.
12 He simply asserts that Descartes was searching for an alternative to a causal

relation (*Perceptual Acquaintance*, 30), but fails to cite texts indicating that this was Descartes' intention.

13 Wilson (op. cit., 294) argues that there is 'a real conflict between ways in which Descartes thinks about the origin of sensory ideas in different contexts', and this seems to me to be true.

14 There are numerous examples of this terminology. The example Wilson gives is from *Traité de l'homme* (AT xi. 149).

15 The main text where this is articulated is the first chapter of *Le Monde*.

16 Wilson, op. cit., 297–8.

17 Yolton, *Perception and Reality*, 199.

18 Although Wilson correctly acknowledges that he does sometimes use terminology like 'impress' which suggests this way of thinking (318 n. 23).

19 There also appears to be a misreading of Wilson, in that Yolton speaks of 'the heterogeneity of causation' (meaning there are two sorts of causal processes) when the heterogeneity Wilson was speaking of was the heterogeneity in nature between mind and body.

20 Yolton, *Perceptual Acquaintance*, 18–19.

21 *Perception and Reality*, 14. Italics mine.

22 Ibid., 190. Italics on 'perhaps' mine.

23 At ibid., 199, he twice juxtaposes the two terms in a way which would seem to indicate that he regards them as interchangeable terms. If they were, then of course the slide in that paragraph from two different sorts of causation to two different sorts of interaction would be legitimate.

24 The underlying reason seems to be his desire to avoid a purely physicalistic account of perception – see, e.g. his argument that those who reject the distinction between causal and significatory reactions will wind up abolishing the significatory and with it, conscious awareness itself (op. cit., 74). Why this should be so, however, is not entirely clear to me.

25 For example, the Port-Royal *Logic* lists 23 different scholastic distinctions within the category of efficient causes: see Gordon Baker and Katherine Morris, *Descartes' Dualism* (London, 1998), 168 n. 5.

26 AT xi. 4.

27 *Perception and Reality*, 209.

28 *Perceptual Acquaintance*, 24.

29 *Perception and Reality*, 8.

30 *Perceptual Acquaintance*, 30.

31 *Perception and Reality*, 209–10.

32 *Perceptual Acquaintance*, 24.

33 Thinkers as different as Aristotle and J.J. Gibson make this point.

34 AT xi. 4.

35 *Perceptual Acquaintance*, 30.

36 I say 'in spite of himself' since he is clearly aware of the dangers of this sort of move, and doesn't want to fall into the error of thinking that we have somehow eyes within our brain with which we can look at the retinal image (AT vi. 130).

37 *Perceptual Acquaintance*, 30.

38 My objection here, is, I think, similar to Catherine Wilson's objection that the semantic account will not work because it requires a 'code reader' and that reading all the nuances of complex brain motions is a feat the mind cannot perform. See her 'Constancy, emergence, and illusions: Obstacles to a naturalistic theory of vision', in Steven Nadler, ed., *Causation in Early Modern Philosophy* (University Park, Penn., 1993), 261.

39 Nicolas Malebranche, *Oeuvres complètes* (Paris, 1958–65), iii. 344. For an extended discussion of the visual theories of Malebranche, Locke and Berkeley,

see my dissertation 'The Retreat from Realism: Philosophical Theories of Vision from Descartes to Berkeley', University of Wisconsin, Madison, 1984.

40 A phrase for which I am indebted to my husband, Phil Devine.

41 This interpretation is supported by his remarks in the last paragraph of the chapter (AT xi. 6) in which he explains that his purpose has been to free his readers from their assumption that light is the same in objects as it is in our eyes, so that they will be open to examine with him now more closely just what light really is. And in the first paragraph also, he states his intention to question the assumption that our ideas are similar to the things from which they proceed (AT xi. 3).

42 *Descartes: An Intellectual Biography* (Oxford, 1995), 287 n. 161.

43 *Perception and Reality*, 208.

44 Ibid., 73–4. Italics added.

45 *International Studies in Philosophy* vol. 21 (1989), 129.

46 *Perception and Reality*, 73, 198.

47 Ibid., 198.

48 Ibid., 204.

49 This point has been made by a number of philosophers, ranging from Thomas Reid to Merleau Ponty.

50 Thomas Reid puts the point nicely when he talks about 'nature working in the dark' or 'being led to our perceptual knowledge in the dark and knowing not how we came by it' in *Essays on the Intellectual Powers of Man,* II. xxi.

51 Ibid.

22d Descartes, Locke, and 'direct realism'

Yasuhiko Tomida

1

In his recent paper, 'Mirrors and veils, thoughts and things', Yolton says that 'the writers on perception from Descartes to Reid [. . .] were attempting to articulate a form of direct realism', and that 'the dominant view about ideas was not that ideas were proxy, inner objects preventing direct access to the physical world'.[1] This interpretation of modern theories of ideas is opposed not only to the 'traditional' interpretation of Descartes and Locke – according to which they put a kind of inner object, *tertium quid*, between our minds and objects – but also to a view such as Rorty's which criticises the modern 'epistemological problematic' on the basis of the 'traditional' interpretation. To make Yolton's basic direction of interpretation clear, I will summarise his central arguments in the paper, in which he asks whether it is valid to regard Descartes' and Locke's ideas as a veil.

Yolton's argument concerning Descartes starts with the union of mind and body in human beings. Then his focus moves to the two kinds of vocabulary employed by Descartes in order to express the relation between mind and body: one is for a causal, and the other is for an occasionalist relation. Furthermore, Yolton presents arguments relating to the distinction and relation between formal and objective realities, and also the significatory relation between physical motions and the ideas correlated with them. From these arguments Yolton draws the following conclusion:

> Each of these components [those relations mentioned above] reflects Descartes' attempt not to isolate the perceiver in the immaterial substance, cut off from the material substance of the perceiver's body and the objects impinging upon it. In humans, these two substances make an intimate union. Ideas are still modes of mind, but in their representative role, they capture the reality of objects that cause reactions in the body; that reality is caught by the cognitive reactions to natural signs in nerves and brain. There are two reactions operating

> in perception: the causal, physiological reaction and the signification reaction. Those who think the difference between causal and significatory reactions distances the mind from objects, isolating the mind among its ideas, need to recognize the alternative, which would be the elimination of the significatory reaction, that is, the elimination of awareness, of cognition.[2]

Briefly, according to Yolton, the relationships between mind and body mentioned above show us the invalidity of the view of the mind isolated in the world of ideas; they suggest *direct* cognition of external objects. Descartes says that the ideas, as modes of the mind, represent objects to the mind; in other words, the mind perceives objects by means of ideas. Traditionally, this view has been interpreted as that which posits a kind of third entity between mind and object. But Yolton objects to this interpretation. He asserts that 'the seventeenth-century notion of representation and correspondence was not based on the notion of glassy essence, mirrors and veils, or inspectable entities'.[3] On what, then, was it based?

Yolton says that 'Descartes denied Gassendi's charge that ideas were images' and that 'the denial of resemblance between natural signs and their causes would also seem to rule out an image interpretation of ideas'.[4] From these points Yolton asserts that the interpretation which regards ideas as images is missing the point. Thinkers such as Rorty take ideas as representations in the mind, but Yolton tells us to treat the phrase 'in the mind' with greater circumspection. He asserts that, as Arnauld did, we should understand the phrase as 'to be understood'. Arnauld, whom Yolton takes to be 'one of Descartes' best expositors', identified the phrase 'to have an idea' with 'to perceive'. Accepting this interpretation, Yolton says 'perhaps we could say that representation *presents* the object to us'.[5]

Thus, according to Yolton, Descartes' ideas are not proxies or images, but acts or operations which present objects to us, and our minds directly perceive objects by the mental operations called 'ideas'. Yolton thinks that Locke took the same view of ideas as Descartes, reasoning that Locke held the same view as Arnauld (for example, Locke says that 'if these Words (*to be in the Understanding*) have any Propriety, they signify to be understood'[6]), and that Locke as well as Arnauld wrote against Malebranche, who treated ideas as special objects. But, at the same time, Yolton himself acknowledges that Locke used Malebranchean wording like '*the Mind* [...] hath no other immediate Object but its own *Ideas*'.[7] Certainly, for Locke, the mind's immediate objects are ideas. But according to Yolton, this does not mean that ideas are placed as a veil between our minds and external objects. As Arnauld says, representationalism is compatible with direct realism; so long as 'to have an idea' means 'to perceive', or 'to understand', our minds directly perceive things by our ideas' representational operations.

Thus, according to Yolton, not only in the case of Descartes but also in the case of Locke, ideas are not special entities placed between things and mind; they are the mind's thinking operations. Therefore, for both of them, our minds are not related to ideas qua veil, but directly related to things.

2

Yolton's interpretation is, indeed, very attractive, but I hesitate to accept it without reservation. To make my suspicion explicit, I will begin by reconsidering Locke's theory of ideas. Both Locke's and Descartes' theories of ideas have a variety of corpuscular physics as their background. So, my reconsideration of Locke's theory of ideas would guide us towards an interpretation of the Cartesian theory of ideas.

Locke certainly says that 'to be in the understanding' and 'to be understood' are the same. But does this mean that he is a direct realist? There is no easy response to this, and certainly we should not jump to the conclusion that the answer is yes. If (as Descartes suggests), when one understands the meaning of a word which refers to an object, we can say that one has the idea of the object,[8] and if in this sense we can say 'to have an idea of an object' is 'to understand the object', then we might call Locke a direct realist. For, even if the object qua something which we understand must be distinguished from the object *simpliciter*, still at least we can say that we *directly* understand what the object is.

But, in fact, when Yolton calls Locke 'a direct realist', he seems to use the phrase in another sense, too. According to Yolton, Locke acknowledges our minds' direct access to 'ordinary objects' (which I call 'experiential objects'[9]), and with this aspect of Locke's theory of ideas in mind Yolton regards Locke's theory as direct realism. He has long exhibited this type of view; the following passage in his *Locke and the Compass of Human Understanding* is an example:

> The so-called 'representative theory of perception' is supposed to be threatened with idealism and privacy; realism is, at best, a postulate or belief. All Locke's use of ordinary physical object and event talk to the contrary, the doctrine of knowledge via ideas seems to clash with his easy talk of observing objects.[10]

I agree with Yolton that Locke's attitude toward experiential objects is direct-realistic, but suggest that the true occupants of the place of things in Locke's theory of ideas are not ordinary objects but 'things themselves', namely, the things which corpuscular physics posits as true bodies.[11] The things themselves have 'primary qualities' and 'powers' based on them alone, and in this sense they are different from the ordinary objects in character. This distinction between two types of objects constructs the basic framework of Locke's epistemological arguments in the *Essay*.

Therefore, even if Locke treated the relation between mind and experiential objects as a direct-realistic one, it does not mean that he viewed the relation between mind and 'things themselves' from the same viewpoint.

To avoid a confusion, we should take note of one point: nowadays when one argues about 'the veil of ideas', one often treats the veil as something which is placed between our minds and ordinary objects. But when Locke asks 'how shall the Mind, when it perceives nothing but its own *Ideas*, know that they agree with Things themselves?',[12] what he is thinking of are not ordinary objects but the 'things themselves' mentioned above, that is, the bodies which have only primary qualities and powers based on them. Therefore, so long as Locke treats the relation between things themselves and our minds, we cannot call his position 'direct realism' and get away with it.[13]

3

With these points in hand, let us turn to Descartes' view. As I mentioned above, Yolton does not think that Descartes' ideas are images. But at least in some cases Descartes treats an image as an idea. In the *Meditationes* he tells Hobbes that 'I am taking the word "idea" to refer to whatever is immediately perceived by the mind',[14] and replies to Gassendi that 'you restrict the term "idea" to images depicted in the imagination, whereas I extend it to cover any object of thought'.[15] It would be clear that these words do not eliminate an image from among ideas. And, in fact, he says:

> [O]utside me, besides the extension, shapes and movements of bodies, I also had sensations of their hardness and heat, and of the other tactile qualities. In addition, I had sensations of light, colours, smells, tastes and sounds, the variety of which enabled me to distinguish the sky, the earth, the seas, and all other bodies, one from another. Considering the ideas of all these qualities which presented themselves to my thought, although the ideas were, strictly speaking, the only immediate objects of my sensory awareness, it was not unreasonable for me to think that the items which I was perceiving through the senses were things quite distinct from my thought, namely bodies which produced the ideas. For my experience was that these ideas came to me quite without my consent, so that I could not have sensory awareness of any object, even if I wanted to, unless it was present to my sense organs; and I could not avoid having sensory awareness of it when it was present.[16]

It is self-evident that the term 'idea' in this quotation refers to an image.[17]

Next we must recognize the fact that Descartes thought ideas which are produced by sensation generally do not have resemblances to the objects which give our minds the occasions of their being produced. According to him, when the motions of bodies are conveyed to the brain via nerves, this physical phenomenon acts as an occasion of the production of our ideas, and, as we find in the cases of colours and sounds, the ideas are often dissimilar to the motions. This type of assertion concerning the dissimilarity between ideas and bodies is conspicuous especially in his physical writings. For example, at the beginning of *Le Monde* he writes:

> The subject I propose to deal with in this treatise is light, and the first point I want to draw to your attention is that there may be a difference between the sensation we have of light . . . and what it is in the objects that produces this sensation within us. . . . For although everyone is commonly convinced that the ideas we have in our mind are wholly similar to the objects from which they proceed, nevertheless I cannot see any reason which assures us that this is so. On the contrary, I note many observations which should make us doubt it.[18]

This passage brings at least two facts to our attention. One is that there can be some differences between ideas and objects. But in a sense the other is more important, that is, the fact that we usually believe that our ideas are 'wholly similar to the objects'. In Descartes' view, a body's true qualities are, solely, extension and its modes. Therefore, our ordinary view of body that regards colour, taste and the like as its qualities is, on this point, inadequate.

The passage of Descartes' concerning the 'significatory relation' which Yolton sometimes mentions[19] can be placed in this context. Yolton's interpretation of the relation – according to which the mind's response to what happens in the nerves and the brain (and hence to what happens in its environment) 'is not a response *caused by* physical events; rather, physical events are *interpreted* by the mind'[20] – is thought-provoking. But in any case, it is true that the passage also emphasises the dissimilarity in question.

In Section 2, I suggested that one of Locke's concerns was the relation between our minds and things themselves. We can say the same thing concerning Descartes, and if so, then perhaps in this case too we should not employ the term 'direct realism'. According to Descartes, bodies are in some respects dissimilar to our ideas (images) of them. Therefore, so far as the relation between our minds and Cartesian ultimate bodies is concerned, we cannot, at least without reservation, treat his view as 'direct realism'.

In the same section I mentioned the possibility of interpreting Locke as a direct realist, in the sense that he identifies 'to have an idea of an object' with 'to understand what the object is'. When Yolton takes up Descartes' notion of 'objective reality' and treats him as a direct realist, his viewpoint might appear somewhat similar. If Descartes' concern is the object that our minds *understand*, then it might be indifferent to him what sensations we have. For even if our sensations are not similar to external bodies, if we understand the external bodies as those which have extension as their 'attribute', for example, then it would mean that we perceive the bodies as our immediate objects. In other words, by treating the bodies as 'intentional objects' our minds grasp what bodies are.

But, for Descartes as well as for Locke, one of the most important problems taken up in their theories of ideas is how to treat the fact that our sensation does not necessarily represent the external objects as they really are. So, it seems to me impossible to understand their theories of ideas as being independent of the problem of the inveridicality of sensation. If our interpretation of their theories of ideas cannot adequately deal with the problematic raised by their corpuscular physics, then we must concede that our account is as yet imperfect.

Notes

1 John W. Yolton, 'Mirrors and veils, thoughts and things: The epistemological problematic', in John W. Yolton, *Perception and Reality: A History from Descartes to Kant* (Ithaca, 1996), 68. This paper originally appeared in Alan Malachowski, ed., *Reading Rorty* (Oxford, 1990), 58–73.
2 Ibid., 74.
3 Ibid., 75.
4 Ibid., 76.
5 Ibid.
6 John Locke, *An Essay concerning Human Understanding*, ed. P.H. Nidditch, (Oxford, 1975), Book I, ch. ii, Section 5.
7 Ibid., Book IV, Ch. i, Section 1.
8 *Meditationes*, AT viii 160: 'whenever I express something in words, and understand what I am saying, this very fact makes it certain that there is within me an idea of what is signified by the words in question'.
9 See Yasuhiko Tomida, *Idea and Thing*, *Analecta Husserliana*, vol. 46 (1995) Part II, ch. 2.
10 John W. Yolton, *Locke and the Compass of Human Understanding* (Cambridge, 1970), 127. Cf. Tomida, op. cit., 79.
11 Locke does not use the phrase 'things themselves' as a technical term, but to understand the history of theory of ideas it is useful to bear in mind the fact that the phrase is a precursor of Kant's 'Dinge an sich', and consequently in this paper I use it exclusively to express the bodies posited by corpuscular hypothesis. In fact, Locke often uses the phrase 'things themselves' to express corpuscularian bodies. The following passage is an example: '[S]ensible Qualities, as Colours and Smells, *etc.* what are they but the *Powers* of different Bodies, in relation to our Perception, *etc.* And if considered in the things themselves, do they not depend on the Bulk, Figure, Texture, and Motion of the Parts?' (Locke, op. cit., Book II, Chapter xxi, Section 3).
12 Ibid., Book IV, ch. iv, sect. 3.
13 Incidentally, as a text which typically shows the transformation of this Lockean problematic, we can take up Kant's argument for the 'Refutation of Idealism' which was added to the second edition of *Kritik der reinen Vernunft*. Interestingly, this argument is for 'the existence of actual things that I perceive outside myself', that is, the existence of experiential objects, and not for that of 'things in themselves'. See Immanuel Kant, *Kritik der reinen Vernunft*, B275. (The trans-

lation is from Immanuel Kant, *Critique of Pure Reason*, trans. and ed. Paul Guyer and Allen W. Wood (Cambridge, 1998) 327.

14 AT. vii. 181.

15 AT. vii. 366.

16 AT. vii. 74–5. See also Descartes' use of 'idea' found in the next quotation from *Le Monde*.

17 Yolton casts doubt on my use of 'image' in such a case. Of course, 'sensation' might be more natural, but since I am thinking of the so-called 'imagistic' aspect of seventeenth-century theory of ideas in mind, I will take the risk of using 'image' here. For a justification of this use, see my 'Yolton on Cartesian Images', in Tadashi Ogawa, Michael Lazarin, and Guido Rappe, eds., *Interkulturelle Philosophie und Phänomenologie in Japan* (Munich, 1998), 105–11.

18 AT xi. 3–4.

19 AT xi. 4: 'Words [. . .] bear no resemblance to the things they signify, and yet they make us think of these things [. . .]. [. . .] Now if words, which signify nothing except by human convention, suffice to make us think of things to which they bear no resemblance, then why could nature not also have established some sign which would make us have the sensation of light, even if the sign contained nothing in itself which is similar to this sensation?'

20 John W. Yolton, *Perceptual Acquaintance* (Oxford, 1984), 30.

22e Response to my fellow symposiasts[1]

John Yolton

Let me begin with some general remarks about what I was trying to do in writing about Descartes in *Perceptual Acquaintance* and *Perception and Reality*. I was attempting to extract from his various texts the outlines of a theory of perception, or some aspects of a theory. Since he did not write a treatise on the subject, or devote a chapter or section to such a theory, any effort to put together passages, hints, suggestions from his writings is bound to be tentative. Wolf-Devine labels such an effort 'rational reconstruction'. It may be, but as that label was used earlier in the last century for an approach to texts that was not particularly concerned with the accuracy of the fit between text and reconstruction, I am chary of accepting that label. She also quite properly warns of the dangers of using material from texts of different times and occasions. An author's views may change over time, he may address different audiences with different languages and purposes. I did not think I was finding tensions in various texts which I then tried 'to harmonise; or to label one of them as his real view and discard the others. I do not find any tensions of conflicts between the various texts I discussed. The question is not 'Are there conflicts?' but rather 'Are there materials for a theory of perception?' I thought I *was* 'painstakingly examin[ing] the terminology Descartes uses to speak about the relation between motions in the brain and our sensations'. That is the way I have always tried to work with an author's text. That my interpretation of Descartes on brain–motion signs, and his epistemic account of the existence of objects in the mind, is debatable, is of course true, that is the value of an exchange such as this symposium. That I do not have an entirely clear explication of the sign-relation between brain and mind, is also true. I hope one result of this symposium will be a better understanding on my part of the view I have suggested can be extracted from what Descartes said.

Causing and signifying

When I was struggling to understand how the mind and body work together in that 'close and intimate union', as Descartes described that relation,[2] it seemed to me that even in that unified whole of mind and body there had to be two different kinds of interaction: one for the body's action on the mind, another for the action of the mind on the body. Descartes does not have much to say about this second interactive relation, other than to say the mind is able to move the pineal gland which in turn activates the animal spirits. But these two interactive relations are matched by another more important dual interaction: that of other bodies on our body's sense organs and brain, *and* those same bodies affecting the mind via disturbances in the brain. What happens in the brain is important for any account of sensation and sense perception. If the processes or events in the brain were just physical, the problem of how those events could cause or relate to cognition would be a puzzle; it certainly was a puzzle for many seventeenth- and eighteenth-century writers. If those same brain events are also signs, if they play a sign (or significatory) role in relation to the mind, then we have a partial solution to the question of the relation between mind and physical objects: the same events that bring about physical (neural) events in the brain, also bring about cognitive events in the mind. They do the latter because, as well as being physical events, they are also signs. They carry information about the objects in the world, the very objects that have affected our sense organs and brain. So we have two interactive relations, a physical causal interaction and a significatory or semantic interaction.

The close and intimate union of what were on Descartes' ontology two different substances poses some fundamental questions for which he did not claim to have answers. In sensing and perceiving, there is an interaction between external bodies and the perceiver's body, but when we become perceptually aware on Descartes' ontology, what results is a non-physical product: the act of being aware and the contents of that act, an idea. How does the non-physical emerge from the physical processes outside and inside the perceiver's body? There is for Descartes an even more challenging feature of sense perception: the object perceived is 'captured' by the non-physical awareness. That what is known must exist in the mind, was of course one of the scholastic principles echoed by Descartes' use of the phrase, 'objective reality'. In the tradition to which this principle belongs, various words were used: assimilation, absorption, translation (from impressed species to intelligible species). Descartes does not use those terms, he even has some critical remarks about the notion of species. Nevertheless, it was important for him to talk of the *being* of the object existing in the mind. The question is, how does he explicate and account for 'existence in the mind'? That question goes along with some account of the transfer from the physical to the non-physical domain.

I think there are two answers to this question. One part of his account of the transfer can be found in that brief, tantalising suggestion in *Le Monde* about nature giving us a sign (as David Behan points out, a natural, and perhaps formal, sign) which 'makes us have the sensation of light'.[3]

There are similar remarks in the Sixth Meditation and in the *Passions*.[4] So the physical motion in the brain becomes for the mind a sign, presumably a sign of its cause (the object) or quality.[5] The physical vehicle has a signifying function. The reaction of the mind to this sign is to form an idea by means of an act of cognition. The sign–vehicle and the act–idea have different roles. Descartes explicitly distinguishes between signifying and representing: *'c'est notre esprit . . . qui représente l'idée de la lumière, toutes les fois que l'action qui la signifie touche notre oeil'*.[6]

Signifying and representing

It was this passage on which in part, I based my tentative suggestion in *Perception and Reality* of a distinction between these two relations. Perhaps the distinction cannot be made to stand, but I think there are differences, functional differences. Signifying is an interactive relation. Descartes uses causal language for it: word-sounds 'make us conceive' of their referents, the brain motion causes the mind to be affected. We should recognize, however, that that interactive relation, that kind of 'making' and 'causing', is rather different from the causing of a brain motion or brain impression by the physical events from objects to sense organs and to the brain. Descartes does not give us any details of signifying causation, other than to compare it to the way words as sounds or marks cause us to think of what they mean or say. Frequently, he resorts to the language of 'occasion', a term which leaves open the parallelism of no interaction (as with Leibniz's pre-established harmony or Malebranche's occasionalism). We may not understand how it is that we interpret certain sounds as words or sentences, but I would think it too weak simply to say, on the occasion of hearing certain sounds, the mind forms (we form) specific ideas. Similarly for brain-motion signs. Especially with the unified whole which mind and body form in humans, it seemed to me that the signifying relation was stronger than 'provide the occasion for'. I saw Descartes' suggestion of brain motions as natural signs as an attempt to find an interactive relation that 'caused' reactions in the perceiver (not just elsewhere in the brain), an interactive relation that was not one of physical causation. Thus, the second interactive relation between mind and body might be described as 'semantic', 'semiotic', or just one of signification.

The representative relation directs attention, as it were, outwards, towards the objects or qualities which started the process of causing changes in the perceiver. To represent is to cognize, to be aware of. This relation gives the other part of the answer to the question about existence in the mind. Here, I looked to Arnauld as the interpreter of Descartes. Arnauld said that phrase, 'exist in the mind' (or to be present to the mind), just means 'is conceived by the mind' (or we might say 'is known by'), and he insisted that this was Descartes' understanding of that scholastic notion. In other words, the being of the object in the mind is epistemic; it is (in a phrase I think I picked up from Norman Wells) *the being of being known.* The epistemic rendering of 'existence in the mind' marks an important shift from an attempted ontic transfer of an object's reality to a cognitive transfer. The explication of 'existence in the mind' does not only occur in Descartes. Behan calls attention to a passage from William of Auvergne which employs the same language: 'What it does mean is that the thing known is in the soul according to the mode of being of the soul, which is cognitive.' This epistemic nature of objective reality fits neatly into the significatory relation between brain motions and the mind.

Is signifying a form of causation?

Both Wolf-Devine and Slezak object to my distinction between signifying and causing. I appreciate their reasons for resisting that distinction, there are conceptual as well as textual reasons for so objecting. It is difficult even to talk about something signifying something else or to someone, without using terms such as 'producing', 'effect', 'bring about'. Descartes frequently uses such terms, as I have also done in trying to explicate what he says. It may not be too important whether we talk of a causal and a signifying relation, or just talk of two causal relations. If there are two relations and if, as I believe, they are different in nature, we need to offer some account of that difference. Wolf-Devine finds the talk of two causal relations 'far less controversial' than my distinction between causing and signifying; it may be, but what account of the sign relation can we offer, or has Descartes suggested? She reminds us of Margaret Wilson's suggestion: 'The brain presents something (a pattern of motion) to the mind.' Does not the talk of the brain 'presenting something' need explicating? Is it any less obscure than saying brain motions signify to the mind? Perhaps Wolf-Devine believes it is self-explanatory. I do not. The two relations, whether both are causal or not, do of course work together: the question is, 'are they the same sort of relation?'

Slezak insists there is only *one* relation and it is 'straightforwardly causal', where 'straightforwardly' means 'purely mechanical and non-intentional'. The sign itself is, he says, 'a mechanical concept of encoding'. Slezak assures us that Descartes 'is concerned with strict causes and effects in a perfectly ordinary sense'. He refers to the sentence I quote from the *Passions*, where Descartes says the motion of the pineal gland causes the soul to be sensible of pain. Slezak insists that Descartes offers here a causal sequence of animal spirits, motion and pain. Allow that it is a causal sequence, but describe the causal step from motion to the *experience* of pain. Is that last step in the causal sequence of the same nature as the steps from external object (e.g. a knife) to nerves in the foot, to animal spirits and to the gland? Or consider the passage from the Sixth Meditation where Descartes also speaks of nature laying it down that 'motion should produce in the mind a sensation of pain, as occurring in the foot'. Can we not ask *how* the pain is produced, describe the causation?

Slezak says that 'Descartes is not searching for an alternative to a causal relation as Yolton suggests but, rather, he identifies the representative abilities of the mind with causal relations which are supposed to "understand themselves".' How are we to interpret the notion of abilities as causal relations understanding themselves? He compares this to the account in the *Dioptrique* of visual images, where 'the images so to speak see themselves'. Apparently Slezak does not think any more needs to be said, even though the phrases 'see themselves' and 'understand themselves' strike me as mysterious; at best, they are metaphors or analogies in need of some careful explanation. Similarly, when he refers to Descartes' 'mechanical account of encoding', he also sees no need for an explication of how the information that is encoded in the brain gets transferred to the mind or, if talk of mind is objectionable, how I become aware of information encoded there.

Slezak grants Descartes the need for a rational soul, 'because of the limitations on such [causal] mechanisms to account for those special features of mind such as language and knowledge which rightly appeared to Descartes to transcend purely mechanical means'. What is required for language and knowledge is apparently not needed for sensation and conscious experience of pain, colour, sounds, stones, tables. What Slezak calls Descartes' 'thoroughgoing strenuous naturalism' (i.e. his commitment to physical explanations?) does not, I take it, apply to the rational soul, to language or knowledge; but it is sufficient to persuade Slezak that no further explanation is needed for the step from information encoded in the brain (as motions for Descartes, as electrical chemical processes for us). I confess, I do share 'the widespread discomfort with purely causal processes'. I do not seek, as he suggests, some additional *mechanism*, if that means *physical* mechanism of Slezak's straightforward and ordinary causation.

The dual nature of ideas

The process from object to idea can also be explained using the Third Meditation principle that there must be as much reality in the cause as is in the effect, and the terminology of formal and objective reality. I want to make a rather odd suggestion here and later, a suggestion that will highlight the dual nature of ideas. Physical motion, I want to say, does not cause ideas, only the mind can cause ideas. The formal reality of the object is carried into the brain by the physical motion outside and inside the body. At that point, the formal reality of the object is embedded (encoded, Slezak wants to say) in brain motion as information. So the formal reality exists in brain motion *as motion* but also *as sign*. Descartes' adaptation of the Aristotelian and scholastic doctrine of the form being able to exist in different media is illustrated here. But whereas the scholastics took the form of the object into the mind via *species impressa*, Descartes locates the form of the object as information in brain motions. The semantic or cognitive transfer (transformation) occurs in the brain. For the completion of that transfer, an interpreter is required, a mind, a perceiver for whom the brain motion is a sign. The meeting of brain motion and ideas as modes of mind results in the idea being particularised and objectified by the information carried in the brain motion sign.

David Behan interprets Descartes' brain motions as formal signs. In support of this interpretation, he refers to the scholastic tradition just behind Descartes, a tradition to which Descartes must have been exposed. As Behan explains, formal signs in that tradition are not themselves known, they signify without our being aware of them. If we read Descartes' suggestion of brain motions as signs in this way, the supposed need, which commentators are fond of insisting on, for a code-reader or, as Wolf-Devine repeatedly says, a homunculus, does not arise.[7] We may have difficulty understanding this scholastic concept of a formal sign, but it does seem to suggest what Descartes may have had in mind. Behan's careful explication of formal signs lends support for my reading of that passage from *Le Monde*, brain motions as formal signs. It is useful to pay attention to Behan's locating Descartes in his scholastic background. We cannot, of course, be certain that Descartes had that notion of formal sign in mind when he made his passing remark about brain-motion signs. Nor do I know whether there were any writers before Descartes who explicitly identified brain motions as formal signs. It may have been Descartes' own application of a scholastic concept to his physiology.[8]

Slezak notes that I have discussed Joseph Glanvill's use (in 1661) of a similar notion of brain motions. I have also shown that that doctrine, for all its strangeness, was developed at more length by Ralph Cudworth in his posthumously published work of 1731, and in even greater detail by Charles Bonnet in two books in 1754 and 1760.[9] What the lineage of this fascinating notion in these writers subsequent to Descartes was, I do not know, but its presence in them may indicate that the notion had a wider application than we might suspect. I do not suppose, however, that these more extensive employments of brain-motion signs will convince Wolf-Devine or Slezak that the doctrine is worth more consideration or perhaps has some value. It turns out not to be just a passing fancy on Descartes' part. I think this wider appearance should make us pause before writing the notion off as implausible or absurd. Slezak has a test for such a notion, it must have 'philosophical merit' or 'philosophical virtue', and it must have 'philosophical grounds'. I need to be enlightened about these 'philosophical' properties and tests.

In any event, if we adopt Behan's account of formal signs and apply it to brain-motion signs, the counterintuitiveness of the reverse-sign relation felt by Slezak should dissolve: no need for the dreaded homunculus, those signs perform their function without our being aware of them. Behan also wants to interpret Descartes' *ideas* as formal signs. To do so I think would reinforce what I see as realism in Descartes' account. It would also avoid the intermediary features supposedly associated with representative theories. There are sound reasons for taking Descartes' ideas in that way, as formal signs, but I think there are some other considerations which may make us pause before accepting that interpretation. Ideas for Descartes are modes of mind. As a mode of mind, an idea does not, to use Augustine's definition of a sign cited by Behan, make 'something other than itself come into the mind.' If ideas represent or if, as Norman Wells suggests,[10] the act of cognizing by means of ideas does the representing (the combination of act and idea), in that function, ideas are not ideas as such. That is, in that representing function, they are not modes of mind. I do not suppose there are any ideas on Descartes' account that are only modes of mind in the narrow sense I am suggesting. I simply want to distinguish their nature as modes of mind from their nature or function as objectively real. It is this objective reality that is in some cases (e.g. the idea of God, some physical objects) caused by something other than the mind. Ideas as objectively real (or the combination of act and idea) do not play a sign role: they simply *are* the objects, that which is known.

I have suggested that the notion of objective reality is an important ingredient in the account of perception implicit in Descartes' writings. Wolf-Devine does not agree with my linking this fundamental notion of the Third Meditation with Descartes' 'more scientific discussion of perception in *La Dioptrique* and *Le Monde*'. I consider Descartes' brief suggestion of a signifying relation in the brain as a part of his epistemic translation of the scholastic concern to 'get the object into the mind' of the cognizer. That is, the signifying by brain motions results in the ideas, or the act-ideas, having objective reality: the object is known because the brain motion *signifies* the object. Signifying would then make us aware of the object, but awareness requires some content, some mental content which is the *idea of an object*. The idea as a mode of mind becomes particularised, becoming *this* rather than *that* idea. The *whatness* of the idea becomes its feature as an idea of something. I suppose for Descartes all ideas are particular (as they were also for Locke), they are always *ideas of* something. The *representing* (not, I think, the signifying) relation holds between the idea particularised and the object. The signifying relation holds between brain motion and the particularised idea. Brain motions as signs could be said to stand between the perceiver and the object, but no more so than brain motions as *motions* stand between the perceiver and the external world. The causal relation here is of a different kind than the causal relation between mind and idea.[11] There is, on the account I am sketching, no causal relation between external objects and the mind. What bridges that gap is the signifying relation of brain motions. In order for us to be conscious of what the brain motion signifies, the ideas caused by the mind must be turned into objective content: that is done by the signifying relation.

There is an interesting similarity in Descartes' account of brain motions and ideas: both play two roles or have two functions. Brain motions are both physical events and signs carrying meaning. The motions become something other than motion. Ideas are ideas *and* objects, modes of mind *and* the object known. In this second role, ideas are something other than ideas. Brain motions become signs *to* a mind. Signs must refer beyond themselves. Ideas as objects do not really refer beyond themselves on Descartes' account: they *are* the objects as known.[12] Thus the relation or function of representation is not a signifying relation, signifying differs from representing.[13] Both are necessary for knowledge and perceptual awareness. The representing function or relation *is* the object itself, the brain motion is not the idea, a sign brings the object (what it is not) into awareness. *To represent* is *to be* that which is represented. The combination of signifying and representing 'gets the object into the mind', that is, makes the object known.

Descartes' realism

If we follow this reading of Descartes, we may find the notion of ideas *being* the objects themselves unclear. We may feel that changing the 'being of the object' (i.e. their formal being) into the 'being of being known' confuses knowledge with reality. I have tried to make some sense of the notion in my *Perception and Reality*, tracing the various forms the notion took in subsequent writers from Descartes to Kant. If sense can be made of this notion, I think we can say it yields a direct realism, a realism we might label 'semiotic'. Other terms have been suggested to catch the realism in this approach.[14] At the end of his paper, Behan indicates that he considers Descartes' non-physiological *ideae* as formal signs also, thereby allowing for another way of understanding a possible realism of Descartes' account. He could make a strong case for this suggestion, a case both conceptually and historically attractive. If Descartes' ideas are formal signs, they are not the objects of our awareness. We do not first cognize or become aware of an idea and then perceive a physical object or its properties. Formal signs work silently to give us a knowledge or awareness of objects.

This way of considering ideas, as formal signs, is firmly rooted in the scholastic tradition. It removes ideas as objects of awareness, takes them out of the cognitive loop, as it were, thereby eliminating the intervening entities of the standard representative theory. Thus, we have another way to find direct realism in Descartes' account. Behan's way of understanding Descartes' ideas is perhaps a more intelligible route to realism than my attempt to make sense of the talk of the being of the object in the mind. But that principle about existence in the mind, which Descartes seems to want to adhere to while shifting it from an ontic to an epistemic interpretation, is, I think, an important component in Descartes' thought. Either way, as Arnauld liked to say, we have representation and realism too, but not a representation by means of intervening entities.

All is not plain sailing towards realism yet. Yasuhiko Tomida's contribution to this symposium raises a difficulty for either approach to direct realism in Descartes (and Locke). Tomida reminds us that for Descartes (and for Locke) there are two different kinds of qualities ascribed to physical objects: those Locke labelled primary and secondary. The latter are perceiver-dependent, at least in part. Thus, if ideas 'capture' the reality of objects, it can only be the primary qualities of those objects which are captured. The objective reality of ideas involves only these properties. This feature of Descartes' account of objects requires some adjustment in our understanding, but it does not alter fundamentally the relation between ideas and objects.[15] Tomida's challenge does not revolve around the primary-secondary distinction alone: it involves the role of the corpuscular theory of matter which both Descartes and Locke accepted. Tomida argues that a direct realism would have to claim that our ideas represent the corpuscular structure of bodies.

In dealing with Tomida's challenge, we need to remind ourselves that the primary qualities for Descartes, and certainly for Locke, are qualities of large-scale objects as well as of the corpuscular structure, of the particles of matter. When, at the conclusion of the proof for the existence of bodies in the Sixth Meditation, Descartes says they may not be quite as they appear to us to be, presumably he means that the large-scale objects of our ordinary experience (the macro objects) do not have the secondary qualities (at least, they do not have them in the same way as they have the primary qualities). He does not mean that physical objects are really only clusters of particles, of insensible particles. Does the problem of our knowledge of the external world involve macro objects or their underlying matter, the corpuscular structure? If the latter, then since the corpuscular structure is insensible, we do not have perceptual knowledge of such objects. Science forms theories about matter, but our knowledge of it, if we have such knowledge, is not perceptual knowledge. If our knowledge of the external world concerns macro objects, then direct realism is possible. What we perceive, what our ideas refer to, are ordinary, macro objects. Depending upon how we analyze ideas for Descartes, they can present the object to the mind with the help of brain-motion signs, the mind can capture their reality. So Tomida's requirement that direct realism for Descartes and Locke would have to involve the corpuscular structure (what he sees as the things themselves in Locke) would of course render direct realism impossible. I doubt that any claims that have been made for direct realism have involved such a requirement. The issue is not: 'Does the objective reality of Cartesian ideas capture the reality of corpuscles?' If we take Locke's talk of the things themselves to refer to the corpuscular structure of bodies, Tomida would be correct to say Locke also is not a direct realist. So if Locke's use of the Malebranchean remark in 4.21.4 is interpreted in this way, then to say that ideas are the immediate objects of the understanding means, in part, that corpuscles are not present to the understanding.[16] Since Locke says the corpuscular theory is the most plausible, he is not making any knowledge claim about matter.[17]

Conclusion

My interpretation of Descartes in *Perception and Reality* should be considered in the context of the history I was tracing in that study, a history of perception and reality from Descartes to Kant. One of the topics found in writers in that time-span was how what is mental (and reality for these writers did include mentality) can know what is physical. That topic was, of course, an old one; modern philosophers inherited various analyses of the relation between mind and matter. One such analysis said that what is known must be assimilated to the mental, to the mind. I see Descartes' use of objective reality as his account of that move from physicality to mentality. For him (at least for Arnauld's reading of him) that transfer was just the move of the object from existence to being known. Somewhere in the causal chain from object to cognizer, the change has to occur, but the change has to be accomplished without, as it were, an ontic switch. Hence, physical brain motions are at once physical and signs, encoded information. Just how those physical signs result in conscious experience may still remain unexplained on the account of Descartes I have offered. Behan agrees that the semiotic relation between brain and mind is obscure; he suggests that perhaps it must remain so. Wolf-Devine believes we are faced with 'a level of brute fact that resists further explanation'. Slezak seems to suggest that an interest in searching for some explanation reflects 'a chronic malaise whose recurrence is symptomatic of deep pathology'. David Hume might agree with this diagnosis; he strove to discard the philosophical attempts to solve the questions of perception and the mind's relation to bodies. I am not prepared yet to accept Slezak's diagnosis of malaise and pathology, especially when Descartes' suggestion of a reverse-sign relation reappears in other writers in the seventeenth and eighteenth centuries, and when much contemporary writing in philosophy of mind and cognitive psychology echoes some of the features of those earlier analyses of perception and reality.

There is another theme I thought I discerned in writers from Descartes to Kant, the theme of the nature of the object of our perceptual awareness. There is a development from Descartes to Kant of a concept of object as experiential, the empirical object. That is what ordinary objects are. The being of being known in Descartes is a component in that development. Locke's concern with nominal essences, with the object as coexisting qualities, is another component or example. Berkeley's ideas that are not modes of mind but the objects themselves (and his explication of 'existence in the mind' as 'known by') took another step. Kant's detailed analyses of representations, and the distinction between inner and outer representations, were an attempt at a definition of objects which, as Brigitte Sassen nicely puts it, makes them (his empirical objects) 'neither representations in us nor objects "truly" outside of or independent of us'.[18] Thus, the realism in these writers' accounts is one of ordinary, experiential objects.

Notes

1 I would like to thank John Sutton for arranging a discussion of my reading of Descartes, and to express my appreciation to the contributors for their careful analyses and critiques. Through such exchanges, our understanding of Descartes can be enhanced. In what follows, I try to explain my interpretation of Descartes by responding to some of the main features of the four contributions to this symposium.

2 *Principia*, Pt. I, §48.

3 *Le Monde*, AT xi. 4.

4 For some brief discussion of these passages, see my *Perception and Reality*, 186–7.

5 In *Perception and Reality*, I said the 'physical stimulus signifies the idea' (186), but this seem incorrect.

6 AT xi. 4–5.

7 I have always found it strange, this worry about a homunculus. Many seventeenth and eighteenth century writers talk of the mind doing things that we normally assign to persons. That way of talking was a result of their faculty psychology, giving to various faculties (sensation, memory, imagination, reason) different tasks. I think no one who used this mode of speech meant to say the mind was a person. Incidentally, it was not, as Slezak surmises, any worries about a homunculus that led me to the reverse-sign relation. Descartes' text took me there.

8 Behan certainly shows that the distinction between instrumental and formal signs was common among many of Descartes' predecessors, but in the passages he cites, I do not find any writers who explicitly mention brain motions as formal signs. Brain motions do not seem to occur in those citations. Perhaps the term 'image', which does occur, refers to brain impressions on the corporeal imagination.

9 See my discussion of these three writers in *Perception and Reality*, 110–12.

10 Norman J. Wells, 'Objective Reality of Ideas in Descartes and Suarez', *Journal of the History of Philosophy* vol. 28 (1990), 36.

11 Ideas as modes of mind are caused by the mind, but that causation is not, I believe, analyzed or explained by Descartes. The three types of ideas mentioned in the *Meditationes*, innate, adventitious and factitious, relate to what I have termed the idea particularized, ideas in their representive objective role. The nature of innateness in Descartes is not all that clear, however. If it just means 'is produced by the mind', then I guess all ideas could be said to be innate, that is, ideas before they become particularised.

12 Cf. Norman J. Wells, ibid., 36. In their objective reality role, ideas do not have objects which they represent: They *are* the objects capable of being represented by the idea taken formally.

13 Behan has sound textual and linguistic reasons for linking these two functions together in ideas or cognitive acts. I want to resist, at least for now, saying ideas both signify and represent. Part of my reason is related to my concern to pre-

serve what I take to be an important doctrine for Descartes, the being of the object in the mind. That may be accomplished on Behan's terms as well.

14 See *Perception and Reality*, 193–209.

15 Ann Wilbur MacKenzie has dealt with this feature in two important articles, showing us how realism (even direct realism) can still be preserved in Descartes' account. See her 'Descartes on Life and Sense', *Canadian Journal of Philosophy*, vol. 19 (1989) and 'Descartes on Sensory Representation: A Study of the *Dioptrics*', *Canadian Journal of Philosophy*, supp. vol. 16 (1992).

16 It is the *understanding* that Locke cites here, not sensation or perception.

17 I think it very doubtful that Locke's use of the phrase 'the things themselves' (sometimes it is 'objects themselves') does refer to the corpuscular structure, certainly not only to that structure. On the theory he accepts from science, the things themselves have a corpuscular structure. But the urge to look to the things themselves is not telling us to examine the corpuscular structure of bodies! However, to appreciate Tomida's interesting treatment of Locke, see his *Idea and Thing. The Deep Structure of Locke's Theory of Knowledge* (Dordrecht, 1995).

18 'Critical Idealism in the Eyes of Kant's Contemporaries', *Journal of the History of Philosophy*, vol. 35 (1997), 446.

Part V

Mind and body, thought and sensation

23 Descartes' intellectual and corporeal memories

Véronique M. Fóti

Surprisingly little attention has been paid to Descartes' recognition of two distinct kinds of memory.[1] One of these is corporeal, or has at least a corporeal basis, whereas the other is intellectual and 'purely spiritual', and is, as such, not found in animals. Corporeal memory is already discussed extensively in the *Regulae ad Directionem Ingenii*, roughly datable to 1628/29[2]; but the doctrine of intellectual memory appears to be closely connected with issues raised in the *Meditationes de Prima Philosophia* of 1641 and is discussed mostly in Descartes' correspondence of 1640–8.

In the *Meditationes*, memory comes into focus most sharply in the Fifth Meditation, where Descartes asserts that, however much he may indeed remember having proved an intermediate conclusion in the course of an inference, he still cannot, once he turns his attention elsewhere, remain assured of its truth without the knowledge that God exists by the inherent necessity of his nature.[3] What is in question in this rather enigmatic text is clearly not the trustworthiness of memory as a 'faculty' or power of the mind; for the a posteriori argument of the Third Meditation suffices, for a Cartesian, to vindicate it. Descartes' phrasing (*quantumvis adhuc recorder . . . modo tantum recorder*), moreover, makes clear that the genuineness of his memory is not in question (he does not just *believe* that he remembers, but *does* remember having proved that *p*).[4]

There is yet another sense in which the whole issue of memory is entangled in the *Mediationes*: what methodic doubt strives to uproot is, in no small measure, the so-called 'prejudices of childhood', which impressed themselves on the mind when it was still immature, but which do not present themselves to the adult as remembered teachings (imparted at a certain time by certain persons), but rather as the unquestionable and immemorial teachings of nature.[5] In the prejudices of childhood, memory masks itself.

Given the intrinsic interest of Descartes' doctrine of memory, as well as the question of how memory functions 'subterraneally' in the *Meditationes*, the present study sets itself the task of analyzing and interpreting Descartes' doctrine of memory from the *Regulae* to the *Meditationes* and beyond, and of exploring its implications.

Corporeal memory and mnemotechnics in the *Regulae ad Directionem Ingenii*

The fundamental concern of this fragmentary early text is, like that of the *Meditationes*, to secure the cognitive foundations of scientific knowledge, with the salient difference, however, that the *Regulae* makes no effort at any metaphysical grounding. Rather, the method that it explicates relies entirely on an epistemology that recognizes the cognitive acts of *intuitus* and *deductio* as the basis of certainty, correlating them with 'simple natures' as the fundamental objects of knowledge. The simplicity of these natures is not intrinsic, but relative to the apprehending intellect. They are distilled from experience by a series of abstractions which, in each case, are brought to a halt when the intellect recognizes that to carry them further (as it might do) could not possibly yield any term still more evidently knowable, but would, on the contrary (as in the case of abstracting the notion of limit from that of figure, which is a simple nature) result in notions that are equivocal.[6]

Intuitus, the instantaneous apprehension of truth in its full, immediate givenness, suffices to grasp the simple natures; but, being non-discursive and limited to present evidence, it does not suffice to ground a systematic science. It must therefore be supplemented by *deductio*, which grasps the necessary interconnections among simple natures – interconnections that obtain precisely because the natures are not absolute simples. Unlike *intuitus, deductio* grasps order and succession, it thus supports the sequential character of reasoning. This means, however, that 'it derives much of its certainty from memory'.[7]

By its very nature, memory is concerned with what is non-present; but the shadow side of its thematisation of absences is that it is notoriously wayward and idiosyncratic. How then can memory be allowed to infiltrate the very foundations of *scientia*?

In the *Regulae*, Descartes deals with this difficulty by severing memory from intellect proper (the *ingenium* or pure understanding) and casting it, along with imagination, as a body-dependent auxiliary cognitive power. Intellect itself can then be protected both against the confusions arising from embodiment and against temporality, whereas memory and imagination can be accounted for in terms of the mechanistic physiology outlined in Rule Twelve. This implies, however, that the pure intellect as such is incapable of scientific reasoning; the assistance that the auxiliary cognitive powers – particularly memory – offer it is strictly indispensable. As Dennis Sepper notes, Descartes, in the *Regulae*, is concerned 'with embodied intelligence'.[8]

This focus on embodied intelligence may possibly explain why Descartes, who already mentions a purely intellectual memory in the *Studium Bonae Mentis*, a text considered to be contemporaneous with the *Regulae*,[9] does not mention any such memory in the latter text. However, the fact that the *Studium* is Baillet's reconstruction of a lost Cartesian text casts doubt on what may be Descartes' earliest discussion of intellectual memory.

To describe the workings of the auxiliary cognitive powers, Descartes resorts, in the *Regulae*, to the metaphorics of imprinting. Memory and imagination originate in sense perception (which is therefore of crucial epistemological importance), in that the senses receive the imprints of perceptible configurations 'in the same way as wax takes on a figure from a seal'.[10] The sensible configuration is, at the same time, conveyed to the *sensus communis* (the 'common sense' of Aristotelian psychology) which is, for Descartes, 'a real part of the body' (presumably the brain). However, whereas the senses are materially affected by their objects, no 'real thing' of any sort is transmitted to the *sensus communis*; but, rather, 'the figures or ideas come from the external senses pure and without a body'.[11] In this instantaneous transmission, matter is mysteriously left behind.

The *sensus communis* now plays in its turn the part of the seal, imprinting the configuration it received immaterially on the material *phantasia*, the seat of memory and imagination in the brain:

> *Phantasia* [is to be thought of] as being a genuine part of the body, and of such magnitude that its different parts can be invested with multiple figures differing among themselves, and can retain these for some time; in this case it is what is called memory.[12]

In its own turn, *phantasia* can inform the 'motive power' (vested in the nerves) which also originates in the brain, thus originating spontaneous movement in response to stimuli. Since non-human animals are, in Descartes' view, strictly incapable of cognitive awareness, the processes outlined suffice to explain their behaviour, although the role of the *sensus communis* remains, in their case, problematic. In the case of humans, who are capable of genuine memory, imagination and understanding, in virtue of a power of knowing that is 'purely spiritual' and radically different from anything bodily, the requisite interchanges between the material and immaterial dimensions are utterly baffling. Descartes remarks that the passive or active interactions between the intellect and the *sensus communis* or *phantasia* can be construed on the model of wax and seal only by analogy; 'for there is nothing at all similar to it among bodily things'.[13]

The analogy by which Descartes can hope to evade the question of how the immaterial intellect or *vis cognoscendi* can possibly interact with a body ontologically alien to it is semantic or hermeneutic in character: the *vis cognoscendi* decodes and interprets bodily configurations, or else it mandates (as, for instance, in doing geometry) a quasi-translation of its own conceptions into the idiom of extension.[14]

Since the pure intellect as such cannot be assisted by sense, imagination or memory, Descartes stipulates that it must steer clear of these auxiliary powers whenever its reasoning is not concerned with anything bodily.[15] Since *deductio* remains, nevertheless, intrinsically dependent on memory (and no purely intellectual memory has been explicitly recognized), the cognitive role of memory is problematic. It can neither be relinquished to the bodily mechanism nor integrated into pure intellection.

Descartes tries to resolve this problem by inventing a mnemotechnics that obviates any need to rely on natural memory, together with its phantasmal basis. Unlike the memory arts practised in his day, however, this mnemotechnics abjures any reliance on images, placement, or resemblances, given that these techniques supplement memory with imagination.[16] By contrast, Descartes' mnemotechnics not only seeks to contract the distension of memory into a virtual present, but also relies on abstract and arbitrary symbols that lack any resemblance to what they symbolise. Being logical and mathematical in character, it is dissociated from the senses and from imagination, and assimilated to the pure intellect.

The psychophysiology of memory and the prejudices of childhood

The general psychophysiology elaborated in the *Traité de l'homme* (originally part of *Le Monde*, composed between 1629 and 1633) differs from that of Rule 12 in that the body is now unequivocally construed as a machine, while the mechanistic physiology is no longer schematic, but is elaborated in full detail. It is called upon to explain all the powers traditionally attributed to the soul (sentience, locomotion, and affect), other than pure thought. This explanatory schema is reasserted in Descartes' classical works, such as the brief discussion of psychophysiology in Part Four of the *Principia Philosophiae* (1644), *La Description du corps humain* (1647/48), and Part One of *Les Passions de l'Âme* (1649).[17]

The rational soul, credited with being solely responsible for thought, has now become an entity in its own right. It is joined to the body-machine chiefly in the pineal gland, so that this humble physiological structure has to bear the burden of accounting for the 'substantial union'. Furthermore, the gland also has to carry out the functions accorded earlier to the physiological bases for the *sensus communis* and *phantasia*. Most importantly, the psycho-topology of Rule 12, which could not explain how motion is communicated, has been complemented by a fully fledged dynamics in the form of a theory of 'animal spirits'; these are, in essence, currents of vital energy derived from rarefied particles of blood that course rapidly from heart to brain, along the short route of an almost straight line.[18]

Descartes now understands ideas as fundamentally material. They are 'the impressions that the animal spirits can receive in issuing forth from the gland H [the pineal gland]', through the mechanisms of perception and imagination. The trace-configurations of these ideas are carried by the blood from the brain to the heart, and from there radiate 'throughout the whole blood' (so much so that, Descartes thinks, they can mark a developing foetus). Above all, however, they imprint themselves upon an area deep within the brain that is subjacent to the pineal gland.[19] This area is the physiological locus of memory, which has become dissociated from the 'seat' of sense-perception and imagination on the surface of the gland, for the reason that these surface entracings must necessarily be ephemeral to allow novelty, whereas memories are unconcerned with novelty and are comparatively lasting.[20]

Memories are entraced by effraction, rather than by mere surface imprinting, in that the impinging animal spirits widen some of the gaps between the small fibres making up the relevant parts of the brain. They also bend and disarrange or rearrange these fibres in a pattern corresponding to that of the original effraction. The repeated and pervasive impact of the animal spirits renders the effraction patterns relatively permanent. Even if the gaps close again, or if some of the fibres return to their initial positions, they remain 'disposed' to disarrange and rearrange themselves in keeping with the effracted pattern.[21] The activation of these dispositions serves, for Descartes, to explain the associative enchainment of memories – the fact that some chance recollection can awaken a whole constellation of memories that happened to be entraced together with it. Along with it, the entire effracted pattern is re-activated. Moreover, Descartes observes, memory also brings about a natural disposition in the body-machine as a whole to imitate 'all the movements which real human beings, or other machines [animals seem to be meant], will make in its presence', so that the soul need not be invoked, even where it is a question of accounting for mimetic behaviour.[22]

Given the natural linkage between memory and imitative behaviour, together with the pliancy and malleability of the infant brain,[23] one can begin to understand why the 'prejudices of childhood' become menacing for Descartes, once he has elaborated his mechanistic physiology of memory. Habits of mind are formed while their formation remains opaque to consciousness. The fact that, in childhood, one does not as yet enjoy the full use of one's reason[24] cannot, of course, be due to any immaturity of the rational soul itself (for what could it mean for a pure power of thinking to be immature?), but rather to the immaturity of the body with which it is intimately united for the duration of human life. It is, admittedly, just as difficult to specify how a body-*machine* could be immature; but Descartes does not address this threat to a mechanistic physiology, being more concerned with the interaction between the mind and body.

Responding to Gassendi in the Fifth Relies, and to Arnauld and Hyperaspistes in correspondence, Descartes concurs that the mind must always think (thought being its essential attribute), even though we have no memory of thinking *in utero*, and though in later life thinking can be 'slowed down by wine', impeded by disease and old age, or even suspended entirely during certain pathological afflictions. These occurrences do not, he argues, indicate that mind is made any more or less perfect by the body, but only that (as he writes to Hyperaspistes) mind is so intimately united to the body as to be constantly affected by it.[25] Since the foetal or infantile brain, or the brain of someone in a state of stupor or delirious frenzy, is physiologically unfitted to encode memory traces, the mind will, in such cases, retain no recollection of its own thinking. Moreover, to accept that the mind always thinks is not tantamount to holding that the foetus meditates 'on metaphysics in its mother's womb'; it is, rather, prenatally and neonatally preoccupied with vital sensations that are powerfully charged with pleasure and pain. If it could, however, free itself of the body it would be in full possession of the eternal truths.[26]

Though unremembered, the experiences of one's immaturity leave lasting marks. The very fact that their formation is unremembered allows them to pass themselves as unassailable 'teachings of nature', while – to say nothing of the added import of imitation – the effractive mechanisms of memory operate most forcefully in the soft tissues of the immature organism. The mind or rational soul will constantly find itself 'occasioned' (Descartes' favoured term in the *Traité de l'homme*) to think along the lines of acquired and culturally sanctioned beliefs. These are re-enforced by early memories of approval, reward, or punishment, whereas nothing in the initial formation of its habits will stimulate the mind to think critically and independently.

Intellectual memory

In June 1648, Arnauld, then living in banishment at Port-Royal des Champs, wrote to Descartes, taking as his first topic of discussion the question concerning childhood amnesia and other 'lethargic' states, which Descartes had spoken to in the Fifth Replies.[27] He asked whether disablement of the brain, in such conditions, really suffices to explain the inability of the mind to recall any of the thoughts that, as a thinking substance, it must have had, whatever one's bodily afflictions. Should not Descartes, in keeping with the real distinction between mind and body, together with his theory of two modalities of thinking (namely, pure understanding and thought that applies itself to 'images in the brain'), also recognize *two* distinct powers of memory, one 'purely spiritual', the other requiring a bodily basis? The first of these will need no bodily organ; but rather, pure intellect must inherently be capable of memory; for otherwise it could not reason about immaterial things. This brings up the difficulty that one would then have to suppose that the unborn child, whose intellect is still unclouded by prejudices and undistracted by the senses, would have a particularly vivid and distinct recollection of its purely intellectual thoughts, rather than having, as appears to be the case, none at all.

As Arnauld could not have known, Descartes had already discussed a purely intellectual memory in correspondence with Mersenne, Huygens, and Mesland since 1640, and in conversation with Burman in April 1648; but his remarks on the topic are sketchy and fail to put forward a coherent theory. He writes to Mersenne on 6 August 1640 that, apart from the corporeal memory that we share with animals, we uniquely possess a purely spiritual memory, and that this form of memory is the one we humans most often employ.[28] A year later, however, he tells Hyperaspistes that there is, properly speaking, no memory at all of intellectual things, but that these are freshly thought of each time they come to mind.[29] In October 1642, he consoles Huygens for a bereavement with the assurance that he has rational evidence of an afterlife that not only promises felicity as well as reunion with loved ones, but also recall of the events of this life; 'for we have, in my view, an intellectual memory which is certainly independent of the body'.[30] The thought here is evidently that, if the soul inherently lacked the power of memory, its discarnate existence would be extremely impoverished, and the idea of a reunion with loved ones meaningless. However, no explanation is given of how a purely intellectual memory should enable one to recall one's concrete life-experiences. Descartes' remark to Mesland, on 2 May 1644, that, whereas the memory of bodily things depends on brain traces, that of purely intellectual matters depends on traces left in thought itself, for which there is no bodily analogue, does little to clarify the issues.[31] Moreover, his comment to Burman that the objects of intellectual memory are universals and not particulars, directly contradicts his remarks to Huygens.[32]

Arnauld's astute questioning seems to have motivated Descartes to reformulate his understanding of intellectual memory. He replied forthwith, if briefly,[33] affirming that he does indeed recognize a twofold power of memory, but that he cannot agree that the unborn or newly born child is capable of intellection. Being freshly united to an immature and utterly dependent body, its mind teems with confused sensations, of which, although they leave traces in the brain, it retains no memories. What is needed for genuine memory over and above brain traces is precisely what the infant's mind is as yet incapable of: 'a certain reflection of the intellect, or intellectual memory'. The latter is needed to compare experiences, and to place them in temporal order.

Arnauld, in reply, asked for elaboration and clarification, pointing out that, if indeed the infant's mind is bombarded with sensations fraught with pleasure and pain, it does not differ, in this respect, from the adult mind which, moreover, is prey to disorienting passions.[34] Arnauld declares himself puzzled by Descartes' identification of intellectual memory with reflection, given that reflection is characteristic of thought as such and cannot, therefore, constitute a special type or power of thinking.

Though Descartes responded to the challenge, he held fast to his stated positions.[35] His reply emphasises the substantial union of mind and body, which Arnauld tends to lose sight of by focusing on their real distinction. Not only is it true, Descartes asserts, that the intellect cannot withdraw itself from the senses when it is in the grip of powerful passions or immediate sensory or emotional experiences, but it also cannot do so when the brain, to which it is 'attached', is in a physiologically unsuitable condition. The brains of young children are notoriously too soft and damp to allow the intellect to manifest its own glory. Notwithstanding the real distinction, the intellect is, in this life, indissociable from its bodily basis, so that, as Descartes points out in *La Description du corps humain*, it is one and the same cause that, at death, renders the body incapable of movement and makes the soul leave the body.[36] He tells Arnauld that, even though the mind does not share the nature of body, it can be called corporeal insofar as it is fit to be united with a body.[37]

Genuine memory, therefore, involves the mind at one with the body. It does not consist in the mere activation of brain traces or the consequent recurrence of certain thoughts; but rather, these thoughts must be recognized as referring back to an initial experience. This in turn requires, Descartes argues, that, at the time the original experience was entraced in memory, the mind must have recognized its novelty and understood it as something discrete (as the infant's mind does not when, in Descartes' example, it suffers gas pains or enjoys the solace of nourishment). This reflective recognition of novelty and discreteness requires an act of pure intellect; it cannot be brought about by the bodily mechanism. Whereas infantile thoughts are (presumably due to the immaturity of the intellect's bodily basis) unreflective, those of any normal adult are reflective. Although the embodied intellect depends on the brain and other bodily structures to carry on its functions, reflection must nevertheless be considered a purely intellectual power.

Since Descartes, in this last formulation, identifies intellectual memory with the power of reflection, and since ordinary memory must involve reflection (without which it would be merely an obsessive pattern of recurrent thoughts), he can no longer recognize a strictly bodily memory that humans would share with animals. Although he is not explicit on the issue, one would have to grant that animals do not possess genuine memory, but that their behaviour attests only to the conditioning of their bodily mechanisms. If the intellect can, according to the real distinction, be severed from the body at death, there is no reason (as Arnauld saw well) why it should not retain its intellectual memory. However, contrary to Descartes' consoling words to Huygens, this inalienable power cannot promise any recall of the experiences of this life.

If Descartes' final assimilation of intellectual memory to the power of reflection leads him to see in ordinary memory a profound expression of the substantial union, it also leads to the realisation that all thought is already permeated by memory in that it is inherently reflective. There can then no longer be any modality of thinking that can lay claim to full and immediate present evidence, such as is ascribed to *intuitus* in the *Regulae*. The whole of a thought is never, so to speak, graspable in a moment of sheer intuited presence; but there is always a reflective distention. Intuitive immediacy can therefore no longer function as a cognitive basis, nor does it any longer make sense to invent a mnenotechnics to counteract the despoilment of an immediacy that has proved illusionary.

On the roles of memory in the *Meditationes*

Gassendi, in the Fifth Objections, criticises the convoluted rhetoric of the First Meditation, its 'artifices, sleight of hand, and circumlocution' in place of simple, straightforward statement.[38] What offends Gassendi, and what Descartes deems necessary, appears to be his recourse to imagination in the progression of doubt. If one reads this progression as a dialogue between the probing skeptic and the ordinary mind ready to accept the so-called 'teachings of nature', the skeptic arrives at his decisive if joyless victory only once he can cast 'metaphysical' doubt on the most evident and, whenever intuited, indubitable truth claims – those of logic and mathematics.[39] The skeptic thus relies on the discontinuity of intellectual intuition, or on the incursion of explicit memory into discursive reasoning. However convincing the skeptic may be, nevertheless Descartes declares that the force of his reasoning is insufficient to make him – that is, his ordinary mind – remember the doubts that were suggested: 'For my habitual opinions keep coming back and, almost against my will, maintain their hold on my credulity, which is, as it were, bound over to them by long-standing habit and the claims of familiarity.'[40] This habit of mind dispenses with strict certainty in favour of a high degree of probability, so that, if it is to be counteracted, the very probability of one's normal beliefs will have to be challenged. Reason supports the probability (though not the certainty) of the accepted foundations of knowledge. Therefore it cannot impress its skeptical conclusions in memory forcefully enough to resist the tidal wave of habitual beliefs that are compelling precisely because one cannot remember ever having initially acquired them. They were 'imbibed' like milk while the intellect was, as yet, incapable of exercising its power of reflection, so that they constitute inchoate or abortive memories. They are like an enemy who will not show his face, and with whom one therefore cannot engage. Descartes wrestles with them by means of a gripping fiction – that of the *genius malignus* – which both springs from and impresses the imagination. In his own striking rhetoric, he undertakes purposely to deceive himself by feigning (*fingere*) that his reasonable former beliefs are 'false and imaginary'. By thus enlisting imagination against his questionable beliefs, he hopes to force himself into a 'toilsome wakefulness' that will not allow him to forget the reality of his bondage, remaining content with the 'imaginary freedom' found in sleep and dreams.[41]

There is no inherent contradiction in employing a body-dependent cognitive power in a skeptical project that will 'bracket' all knowledge claims as to the nature and existence of bodies, until they can, within certain limits, be validated. Descartes uses a similar strategy in the Second Meditation, where, in the interest of counteracting habitual patterns of thought, he allows his senses and imagination free rein to show what they can contribute to his knowledge of a particular body (the piece of wax), thus bringing them up against their limits.

For the skeptical philosopher, imagination is a powerful tool. Although it shares the bodily basis of memory, it is unlike memory in being a free power of invention pliant to the intellect. It can therefore be called upon to counterbalance the weight of received opinion, to which reason tends to acquiesce, by a compelling fiction, in keeping with the Pyrrhonian technique of equipollence. If, however, the human mind were not beset by 'the preconceived opinions of childhood', which are difficult to expunge from memory, it would not be prone to delusions so entrenched or so resistant to reason that they must be combated by fiction. Moreover, as Descartes writes in the Fifth Meditation and in Part One of the *Principia*, if it could also more readily withdraw itself from the senses, it would spontaneously and lucidly understand that God's essence involves his necessary existence.[42] It is clear from Descartes' responses to the authors of the Second Objections (which were probably mostly written by Mersenne) and to Gassendi that his version of the a priori theistic argument hinges on the inherent necessity of the divine existence.[43] This necessity is important because, according to the Fifth Meditation, it underlies the possibility of certain and perfect knowledge. Without ascertaining it, one would be limited to shifting and changeable opinions; for, as soon as one's attention is no longer focused on an evident truth, so that one's evident grasp of it is replaced by a memory of having understood or demonstrated it, doubt can once again assail it.[44]

Although doubt here is coextensive with reliance on memory, it cannot, as several commentators have noted, concern the trustworthiness of memory.[45] Not only is Descartes, as already noted, quite sure that he does indeed remember, while memory cannot, by the reasoning of the Third Meditation, be intrinsically fallacious, but he has also, as John Etchemendy has pointed out, already relied on his memory in formulating the a posteriori theistic argument, which is too complex to be intuited. Etchemendy also remarks that, if memory were at issue, one would expect to hear far more about it in the *Meditationes* and in the exchange with Burman than is in fact the case.[46] Moreover, Descartes states in the Second Replies that, given knowledge of God, one may even forget the arguments for a conclusion one remembers having demonstrated without jeopardising one's 'firm and immutable conviction' as to its truth.[47] The weakness of memory can thus be admitted without endangering *scientia*.

In what way, then, does the necessity of the divine existence and nature allow him to be so cavalier about the lack of present evidence that memory entails, and even about failures of memory? This question needs to be addressed with reference to Descartes' doctrine of the created status of the eternal verities – a metaphysical doctrine which he first put forward in correspondence in 1630, and which he never abandoned, although he publicly acknowledged it only when pressed by Gassendi and by the authors of the Sixth Objections.[48] Although this doctrine and its discussion in the scholarly literature are too complex to be analyzed here,[49] its interconnections with the question of memory can, in conclusion, be explored.

In his detailed discussion of the doctrine in his letter to Mesland of 2 May 1644 (a letter which is also, as previously noted, an important source on intellectual memory), Descartes explains that the finite mind is constrained to regard as possible whatever God, by his act of creative understanding, has decreed to be so, whereas it cannot genuinely conceive of whatever God has decreed to be impossible (for instance, that the law of non-contradiction might not hold). All possibility and necessity, binding as they are for finite thought, are instituted by God's free creative act.[50] The obvious problem this raises for *scientia* is that, in its unavoidable reliance on memory, the finite mind must assure itself that the truths which it remembers having demonstrated are ontologically stable – that is, that God's understanding of them is, though entirely free, immutable. If this cannot be established, remembered conclusions will be no more than inconstant opinions; and even if, *per impossibile*, the finite mind could dispense with any reliance on memory, it would lack the assurance that the truths which it now unwaveringly intuits will necessarily remain constant.

It must be admitted that Descartes, secretive as he is about the eternal truths doctrine, does not give as full an explanation as one would wish of just how the recognition of the intrinsic necessity of the divine existence and nature removes the difficulty; but there is little question that the theistic reasoning of the Fifth Meditation is intended to lay it to rest.

There is still a further and more subtle issue to be considered here. If intellectual memory is tantamount to reflection and is therefore inherent in thought as such, there is no thought or form of thought whose sheer present evidence would grant it immunity against being despoiled by memory. Even the cogito cannot be considered an exception, being, as it is, a pure reflective realisation. Jean-Marie Beyssade has argued convincingly that the *cogito* cannot be instantaneous but is, in fact, durational.[51] If so, the incursion of memory into what seems to be pure present evidence can explain how God could conceivably bring about that one is deceived even as to what one 'seem[s] to intuit most evidently in the mind's eye', although, as soon as one turns one's attention back to a truth such as the *cogito*, one can in no way conceive that 'I should be nothing while I continue to think that I am something'.[52] This 'metaphysical' reason for doubting can only be removed by insight into the inherent necessity of the divine existence and nature. The pervasion of all thought by memory has here revealed itself as, so to speak, the 'mechanism' by which radical deception, or the utter disjunction between intellectual evidence and reality, could possibly come about, so long as Cartesian epistemology has not secured its own ontological basis.

Notes

1 See Paul Landormy, 'La mémoire intellectuelle et la mémoire corporelle chez Descartes', *Bibliothèque du premier congrès international de philosophie* (Paris, 1902); J.H. Roy, *L'Imagination selon Descartes* (Paris, 1944); and Paolo Rossi, 'La memoria artificiale come sezione della logica', *Rivista Critica di Storia della Filosofia* vol. 15 (1960), 22–62. I have earlier touched on the topic in my 'Presence and Memory: Derrida, Freud, Plato, Descartes', *The Graduate Faculty Philosophy Journal*, vol. 11 (1986), 67–81. David F. Krell, *Of Memory, Reminiscence, and Writings: On the Verge* (Bloomington, 1990), also touches on the topic from the perspective of contemporary European philosophy. Dennis L. Sepper's interesting study, 'Ingenium, Memory Art, and the Unity of Imaginative Knowing in the Early Descartes', in Stephen Voss, ed., *Essays on the Philosophy and Science of Rene Descartes* (Oxford, 1993), 142–61, is mostly devoted to Descartes' understanding of imagination; but, as Sepper recognizes, imagination is, for the early Descartes, intimately bound up with memory.

2 Apart from AT and the Cottingham et al. English translation, I have consulted Jean-Luc Marion's annotated translation, *Règles claires et distictes pour la direction de l'esprit en la recherche de la vérité* (The Hague, 1977), together with Gregory Sebba's review, 'Retroversion and the History of Ideas: J.L. Marion's Translation of the *Regulae* of Descartes,' *Studia Cartesiana*, vol. 1 (1979), 145–65, and E. Springmeyer, L. Gäbe, and H.G. Zekl, ed. and trans., *Regulae ad Directionem Ingenii/Regln zur Ausrichtung der Erkenntniskraft* (Hamburg, 1973), which is also annotated.

3 AT vii. 69–70.

4 AT vii. 70.

5 For Descartes' detailed account of the 'preconceived opinions of childhood', see his *Principia Philosophiae*, I, art. 71, AT viii-A. 35f.

6 Rule 12; AT x. 418.

7 Rule 4; AT x. 370.

8 Sepper, op. cit., 156.

9 *Studium Bonae Mentis*, AT x. 200f.

10 Rule 12, AT x. 412.

11 Rule 12, AT x. 80. Ideas, in the *Regulae*, are of corporeal origin, even if, as here, they may be immaterial. They can be understood as phantasms.

12 Rule 12, AT x. 414.

13 Rule 12, AT x. 415.

14 Compare here J. Yolton, 'Perceptual Cognition with Descartes', *Studia Cartesiana* vol. 2 (1981), 63–84.

15 Rule 12, AT x. 416–17.

16 Descartes himself discusses Lambert Schenckel's *De Arte Memoriae* in the *Cogitationes Privatae* (AT x. 230). See further Sepper, op. cit., and Frances A. Yates, *The Art of Memory* (Chicago, 1966).

17 *Principia Philosophiae*, IV: §§189–98, AT viii-A. 315–23.

18 AT xi. 177f.

19 AT xi. 178. See Figure 38 in the text for the brain location of memory, marked B.

20 AT xi. 178f. See also Descartes to Mersenne, 1 April 1640, AT iii. 147f, for Descartes' view that, in particularly dull-witted people, memory traces may be inscribed transiently on the pineal gland itself.
21 Ibid.
22 AT xi. 185.
23 Descartes generally describes the infant's brain as being soft and moist. See, for instance, Descartes for [Arnauld], 29 July 1648, AT v. 219.
24 See, for instance, *Discours de la méthode*, AT vi. 13.
25 Descartes to Hyparaspistes, August 1641, AT iii. 424.
26 Descartes to Hyperaspistes, August 1641, AT iii. 423.
27 [Arnauld] to Descartes, [3 June 1648], AT v. 184–8.
28 Descartes to Mersenne, 6 August 1640, AT iii. 143.
29 Descartes to Hyperaspistes, August 1641, AT iii. 425.
30 Descartes to Huygens, 13 October 1642, AT iii. 580.
31 Descartes to Mesland, 2 May 1644, AT iv. 114.
32 *Entretien avec Burman*, 16 April 1648, AT v. 150ff.
33 Descartes for [Arnauld], 4 June 1648, AT iii. 192ff.
34 [Arnauld] to Descartes, July 1648, AT v. 211–15.
35 Descartes for [Arnauld], 29 July 1648, AT v. 219–24.
36 AT xi. 225.
37 Descartes for [Arnauld], 29 July 1648, AT v. 223. Compare Descartes to Hyperaspistes, August 1641, AT iii. 424; and Descartes to Princess Elizabeth, 28 June 1643, AT iii. 694.
38 AT vii. 257ff.
39 AT vii. 20f.
40 AT vii. 22.
41 AT vii. 22–3.
42 AT vii. 69; AT viii-A, 10–11.
43 AT vii. 163–6, 383.
44 AT vii, 69–70.
45 H.G. Frankfurt, 'Memory and the Cartesian Circle', *Philosophical Review* vol. 71 (1962), 504–11; A. Kenny, 'The Cartesian Circle and the Eternal Truths', *Journal of Philosophy* vol. 67 (1970), 685–700; G. Rodis-Lewis, 'Note sur le cercle cartésien', *Bulletin Cartésien* vol. 8 (1979), 22–6; and David Scott, 'Doubt and Descartes's a priori proof for God's Existence', *The Southern Journal of Philsophy* vol. 19 (1992), 101–16. There is, of course, a close connection between the role of memory in the *Meditationes* and the question whether Descartes' reasoning is circular. Compare *Responsiones Quartae*, AT vii. 245–5.
46 John Etchemendy, 'The Cartesian Cycle: Circulus ex tempore', *Studia Cartesiana* vol. 2 (1981), 5–42.
47 AT vii. 146.
48 AT vii. 380.
49 See Willis Doney, *Eternal Truths and the Cartesian Circle* (New York, 1987), and the contributions by J.-M. Beyssade, G. Rodis-Lewis, and G. Simon to the 1981 conference on the eternal truths at the *Centre d'études cartésiens*, in *Studia Cartesiana* vol. 2 (1981), 85–124.
50 Descartes to [Mesland], AT iv. 118–19.
51 Jean-Marie Beyssade, *La Philosophie première de Descartes* (Paris, 1974), 135.
52 AT vii. 36.

24 The senses as witnesses

Gordon Baker

> Whatever I have accepted up until now as most true [*maxime verum*] I have acquired either from the senses or through the senses. Yet I have found that these senses sometimes deceived me, and it is a matter of prudence never completely to trust those persons [*nunquam illis plane confidere*] who have deceived us even once.[1]

This passage introduces a discussion built on a sustained metaphor of treating the senses as unreliable witnesses (hereafter referred to as 'the witness-metaphor'). It is the opening shot in Descartes' exposition of the strategy of 'methodological doubt'; indeed the initial move in his ambitious project to demolish the whole edifice of his so-called 'knowledge' and to rebuild it afresh on solid foundations. Though one of the best known and widely discussed bits of the text of the *Meditationes*, the argument is not well understood, at least not by many twentieth-century Anglophone analytic philosophers.

After some preliminary points of clarification, I look into difficulties that prevalent interpretations encounter. These seem to originate in a particular reading of Descartes' deceptively familiar witness-metaphor. I shall argue that he had clear, and clearly different, intentions in exploiting this metaphor, and I shall try to elucidate how he (and his educated contemporaries) understood it. Finally, I suggest some important implications of this novel reading for grasping the overall structure and programme of the *Meditationes*. Here, as so often in philosophy, *finis origine pendet*; unless a line of reasoning is grasped exactly, we get stuck in trying to follow it just as a railway carriage cannot roll at all unless it has been placed squarely on the tracks.

1

Our first task in this *explication de texte* is to establish what exactly is the intellectual practice to which I have adhered up till now. What does it mean to say: 'I have followed the principle that whatever I have taken to be most true I have acquired from the senses and through the senses'?

This is more problematic than it might seem. In particular, three points may be missed by modern readers. First, Descartes followed the contemporary practice of allocating the cognitive operations of the soul to three faculties: sense, imagination, and intellect (reason or understanding).[2] In clarifying and scrutinising knowledge-claims, he also followed the practice of tracing them back to the faculties exercised in their acquisition. Indeed, he recommended the general policy of always investigating the sources of our knowledge.[3] He put this into practice himself, conspicuously in the second half of Meditation II. Consequently, he might be expected to contrast the principle 'whatever is most true I have acquired from the *senses*' with the very different principle 'whatever is most true I have acquired from the *intellect*' (and possibly also with the corresponding principle about the *imagination*[4]). He would surely have expected his readers to have these contrasts in mind. They were the framework of a venerable and still vigorous intellectual debate in the seventeenth century. If he wanted readers *not* to consider how to compare the *faculties* with each other in respect of their reliability, he would have had explicitly to divert them from this topic.[5]

Second, Descartes followed the Aristotelian tradition of recognizing certain 'internal senses' (two in number, in his view)[6] in addition to the five external senses (sight, hearing, taste, touch, and smell). So 'the senses' must be understood to include the two inner senses, common to man and higher animals, by which organisms monitor the states of their own bodies.[7] In his view, pleasure and pain are the dominant forms of *sense*-experience in infancy.[8] He also argued that judgments about pleasure and pain provide scope for 'deception by the senses'.[9] Most modern commentators pay no attention at all to his doctrine that (animal) pleasure and pain, all bodily appetites (hunger, thirst, lust, etc.) and all basic emotions (fear, joy, anger, etc.) are objects of *sense*-perception; hence they treat as paradigmatic 'mental states' things that Descartes took to be features of animal (soul-less) sentience,[10] they mistakenly restrict the scope of his discussion in Meditation I to 'what is acquired from the *external* senses', and they blur the boundary between reason and the senses by treating *conscientia*[11] as 'inner *sense*'.

Third, the intended contrast between the phrases 'from the senses' and 'through the senses' is certainly not transparent now, probably not even to readers in his day. Puzzled by it, Burman asked Descartes to clarify the distinction. Here is the recorded reply:

> From the senses: i.e. from sight, by which I have perceived colours, shapes, and such like. Leaving aside sight, however, I have acquired everything else through the senses, i.e. through hearing; for this is how I acquired and gleaned what I know, from my parents, teachers, and others.
>
> (AT v. 146)

This account is multiply problematic, almost certainly garbled. The point *seems* to be to distinguish between what I acquire through my own sense-experience (presumably by all seven senses!) and what I learn from others. If so, the same distinction is drawn in other related texts: viz. in the comment that the knowledge that each person acquired as a child 'was based solely on the weak foundation of the senses and the authority of his teachers'.[12]

This explanation generates an important ambiguity about the scope of 'what is acquired through the senses'. On a narrow reading, it might be restricted to what others have themselves acquired from sense-experience, especially to knowledge of distant places and events (geography and history) based on the testimony of eye-witnesses.[13] On a wide reading, it might include everything taken to be a standard part of the educational curriculum, including arithmetic, Euclidean geometry, moral principles, and 'common notions' of logic and metaphysics.[14] This ambiguity opens up the possibility (usually neglected) that the principle 'whatever is most true is acquired from the senses *and through the senses*' may be meant to embrace some a priori judgments as well as empirical ones.[15] And this might further license a quite unfamiliar reading of 'deception by the senses' (viz. to include deception by false testimony).

These three observations impose some constraints on how to read the opening sentence, hence too on the adequacy of any interpretation of the whole quoted passage. There are other more general ones. We need to show the thematic continuity of this passage with what precedes it and with what immediately follows it. We should respect the details of Descartes' text, preferably making good sense of them. Finally, we ought to take into account the general background to, or framework of, his reasoning. (These blank cheques will be filled in later.) All of this suggests that interpreting even the first sentence requires not only examining it under a microscope, but also taking a wider look around.

Our primary problems of interpretation must be simultaneously to answer a number of pressing questions. What did Descartes mean by speaking of *principles*? How is 'most true' to be understood? In whose voice, or voices, are uttered the various comments about the reliability of the senses? (Who is 'I', from case to case?) What are the implications of noting that the senses are not wholly reliable witnesses? What is envisaged as the range of possible witnesses? And what are the criteria of identity for individual witnesses? Finally, what is meant by the claim that in some cases the testimony of the senses 'cannot be doubted'? All of these issues turn out to be intimately intermingled and conjoined.

2

For the moment we postpone consideration of what Descartes understood by the term 'principle' (*principium*) in his search to lay bare 'the basic principles [plural] on which all my former beliefs rested'. Instead we shall go straight for the content of the principle (singular!) which determines what up till now I have taken to be most true. Settling this question, it seems, cannot be divorced from ascertaining the content of the antithetical principle recommended on the grounds that the senses are known sometimes to have deceived me. Both require clarifying one important aspect of the metaphor of the senses as witnesses.

The now standard interpretation of the initial policy takes the speaker to be naive, even infantile, somebody so 'immersed in the body' as to be limited to making simple perceptual judgments and unable to make any distinction between appearance and reality.[16] This philosophical ingénue follows the policy of accepting as true everything that comes from the senses, i.e. of judging that corporeal things always have just the sensible properties that they seem to have.[17]

Correlatively, the prevalent interpretation of the second antithetical principle is the paraphrase 'never trust the senses'; in view of occasional deception by the senses, we are to suspend judgment on *every* single sense-based thought (or 'perceptual proposition').[18] Formulating this excessively cautious policy[19] is seen as prefacing a futile attempt to discover a sensory criterion for distinguishing 'veridical' from 'non-veridical' (or 'delusive') sense-experiences. The next paragraph opens with an objection to the policy, and that, in turn, is later overturned by 'the Dream Argument'.[20]

Though the witness-metaphor is left unexamined, it is given a quite particular interpretation. Two crucial questions are answered by implication: the range of possible witnesses and the criteria of identity for a single witness. It is presupposed that sense-perceptions can be contradicted only by other sense-perceptions;[21] and that each sensory thought is treated as the report of a fresh witness, though one who belongs to a class of witnesses already known to be unreliable (viz. sense-perceptions). 'The epistemological problem of perception' is to extract solid knowledge from this chaos of *independent* reports. What we need is a criterion for judging the truth of individual sensory judgments – or, equivalently, it seems, the 'veridicality' of the sense-experiences on which they are based. According to this account of the witness-metaphor, each of us is, as it were, an editor of a paper trying to gather all the news fit to print by sitting in his office and receiving telephone reports of current events from unknown (or even anonymous) callers. In this situation, we would surely be rash (imprudent) to put firm trust in any single report. If you are in any danger of losing sight of the wisdom of this cautious policy, just remind yourself how many gossips, rumour-mongers, slanderers, and plain liars there are 'out there'! That *must,* it seems, be Descartes' point in reminding us about past instances of deception by the senses.

This interpretation raises serious problems. In respect of the initial principle, it distorts the logical form of the universal statement (reading 'All Bs are As' instead of 'All As are Bs'), ignores the qualification 'most' attached to the term 'true', and pays no heed to Descartes' explanation of the phrase 'through the senses'; it misconceives what he meant by '*deception* by the senses'; it destroys the continuity with the preceding two paragraphs[22] (which appear, like the text of the *Discours*, to be deliberately autobiographical and not the assumption of some fictitious *persona*[23]); and it generates further discontinuity with what comes a few paragraphs later (especially because 'all my former beliefs' evidently must include simple arithmetical and geometrical judgments[24] which are evidently not acquired from the senses even if their constituent concepts are).[25] Likewise, this interpretation ignores the term 'completely' in the counter-principle. Finally, it makes nothing of the contrast between witnesses and bits of testimony which is built into Descartes' use of the witness-metaphor: he immediately canvassed the suggestion that some particular *reports* may be indubitable even though they are issued by *a witness* who has sometimes deceived us and hence is unworthy of our *complete* trust.

On the other hand, the familiar interpretation has three merits. First, it seems required to respect Descartes' own description of the identity of the speaker: 'The author is considering at this point the man who is only just beginning to philosophise and who is paying attention only to what he knows he is aware of.'[26] Second, it does homage to the well entrenched modern principle that an empirical statement can come into conflict only with other empirical statements – so that the class of witnesses must be homogeneous, like the class of empirical judgments. Third, it takes the whole text to raise one of the main problems of modern philosophy: viz. how to build knowledge of the external world on the basis of immediate sense-experience (from the *external* senses!). On this understanding, we all know how to proceed with analyzing Descartes' argument and exposing its deficiencies. (Otherwise, what on earth could we take him to be doing?) These are all powerful motives, if not good reasons, for being content with the *status quo*.

Within this family of interpretations,[27] the witness-analogy has evoked very different responses from Anglophone analytic philosophers. (That they pay so much attention to it is interesting in itself, but I shall not here explore the reasons for that.) In fact, there are two prominent antithetical reactions to *the* [sic!] analogy of the senses with witnesses; or more precisely, *the* analogy of sense-experiences with reports of events. One is extremely hostile; the other very enthusiastic.

The first reaction, prominent in Ryle, takes the witness-metaphor to be useless, or even worse than useless. On the supposition that Descartes' project was to clarify the epistemology of sense-perception, the principal task must be (allegedly) to explain when it is rational to take appearances to be 'veridical', i.e. when we can justifiably take sense-experience to be an accurate guide to how things really are in 'the external world'. Invoking the comparison of a sensory appearance with the testimony of a witness cannot help with this problem. The testimony would have to be the report of the sensible properties of corporeal things, so that the witness would have to be an *observer*. Consequently the problem whether to accept the witness' testimony about how things really are boils down to the problem in what circumstances sense-experience gives *anybody* genuine knowledge of the external world. Applied to particular sense-experiences, the witness-analogy simply reduplicates the original problem without making any progress towards solving it. Hence it is, at best, an idle wheel in the epistemology of perception: it is 'to push back the question of the sources of error by one stage'.[28]

In fact, Ryle argues, it is worse than useless. Verbs of sense-perception such as 'see' and 'hear' are achievement-verbs, whereas verbs used in describing how to process and assess testimony are task-verbs. Consequently, the witness-analogy is to be condemned for committing a category-mistake, for amounting to 'an attempt to fit familiar generalities about perception, delusions, misestimates, deafness, etc., into an unsuitable conceptual harness'.[29]

The second reaction to the witness-metaphor, now widespread, takes it to introduce an information-processing model of sense-perception. (This is a Good Thing!) Like witnesses, the senses convey *information* about the external world; they *tell us* how things are. This information is encoded in sensory stimuli and decoded by the brain or mind. (The mechanism of this information-processing is the subject matter of cognitive science.) Sense-experiences are intermediaries in transferring information-states of perceived objects into articulate perceptual propositions. In this role, they are precisely parallel to witnesses who bring us reports about the states of things outside our perceptual reach. The primitive model of receiving information is grasping a broadcast news-report. Hence, the witness-metaphor is held to capture a valuable insight in virtue of its dramatising the idea that the senses convey to us information about the sensible properties of material things.[30] It is, one might say, 'a full-blown pictorial representation of our grammar'.[31]

These two interpretations of the witness-metaphor may seem altogether different, but they really have a lot in common. Both take the deliverances of the senses to be something *opposed to* articulate thoughts. (Prima facie, this is a serious departure from the witness-metaphor. As if testimony could be something inarticulate!) In this respect, both misrepresent what Descartes called 'sense-perception [*sentire*] in the restricted sense'.[32] His metaphor concerns *rational* sense-perception, a faculty of the rational soul (which is exercised in making sensory judgments), hence not a faculty of animal sentience.[33] Both interpretations focus on a comparison that Descartes *could not* have made.

Neither makes sense of his concept of *deception*, either by testimony or by the senses. Error is to be found only in judgments! Descartes is concerned with falling into *error*. In his view, error can arise only from making a false *judgement*, i.e. of wrongly assenting to a thought or proposition.[34]

Neither makes any use of a contrast between witnesses and pieces of testimony; nor between assessing the reliability of a witness and evaluating the circumstances surrounding a particular report. Both omissions are noteworthy. The issue is whether a particular bit of testimony can be *differentiated* through being rationally discounted or discredited by reference to the character of the witness,[35] and this can be raised only if there are multiple witnesses and only if some *individual* witnesses are identifiable as the sources of *multiple* bits of testimony. (Twentieth-century conceptions of the analogy logically exclude this possibility.)

Neither interpretation considers the possibility that testimony of the senses might conflict with testimony from a *different* source. But Descartes repeatedly considered situations where the senses and the pure intellect at least *seem* to come into conflict.[36] Moreover, the contrast of the senses with other faculties as various sources of knowledge seems to be present in Meditation I, certainly by ¶6, and arguably from the very opening! As already noted, a seventeenth-century reader would surely have had this contrast in mind in reading ¶3. (The analogy has a different 'geometry' if it is taken to rule out the intelligibility of any conflict of any testimony of the senses with anything external to the senses.) Modern uses of the analogy have in the background the principle that any judgment grounded in sense-perception *can* be contradicted *only* by other sense-based judgments; indeed, they presuppose that reason and sense-perception, as different sources of knowledge, generate sets of truths that are necessarily disjoint, say empirical propositions and logical truths (tautologies).[37]

Neither interpretation considers whether Descartes might have had a *specific* purpose for drawing the analogy; or indeed, whether it might be used by different authors on different occasions for different purposes. As we shall see, there is certainly at least one possibility that is not now considered. What we call '*the* analogy with testimony' is a ready-made product. We look for this old friend in discussions of sense-perception and, because we have this mental set, we often seem to spot *it* where we look for it, say in Meditation I. (In the same way, we may come to philosophical texts ready-armed with the accusation 'quantifier-shift fallacy'.[38]) Perhaps we would do better were we to think of analogies as one-off, purpose-built constructions – at least in authors as sensitive, intelligent and original as Descartes.

There are indications that the most prevalent interpretations of Meditation I ignore essential features of the witness-metaphor as Descartes used and understood it. We need to start again from scratch and establish what his *purpose* was in introducing it. We can then see that its content is different from anything given serious consideration by modern Anglophone philosophers.

3

Let us return to the quotation and pay particular attention to features of the text previously ignored. The principle that I have followed up till now is that whatever is *most true* has been acquired via the senses.[39] Apparently, this applies quite generally to thoughts or judgments that make up the body of knowledge that I have always taken myself to possess. Two things are noteworthy here. First, the principle is a restrictive one, a limitation on the sources of what I have taken to be most true; it is by no means a blanket endorsement of the senses. Second, the phrase 'most true' suggests that there are different *degrees* of truth. Apparently, things can be more or less true, and what is most true must have a higher degree of truth (or be more true) than anything which is not most true. The principle I have followed has been to restrict the *highest* degree of truth to what has been acquired via the senses.

This initial attempt to clarify the principle yields two clear problems. First, what is to be contrasted with what is acquired via the senses? The *restrictive* principle makes sense only if there are things *not* acquired via the senses which have been assigned a lower degree of truth than some things that have been acquired via the senses. Otherwise it would be vacuous. In fact, it seems to require making sense of the idea that what is acquired via the senses can be directly in competition with what is acquired in some other way, i.e. that the scope of competence of the senses overlaps in some substantial way with the scope of some other sources of knowledge. Second, what could it mean to speak of 'degrees of truth', or to call one judgment 'more true' than another? This is prima facie nonsense! A thought is either true or false (*simpliciter*); there are no intermediate positions between 'true' and 'false', no scale of possible readings, and hence, too, nothing higher on the scale 'true/false' than the reading 'true'. Is there any logical space to be occupied by the property 'most true'?

The first of these questions has a plausible answer. We have already noted that Descartes' contemporaries regularly contrasted different cognitive faculties (especially the senses with the intellect) as distinct sources of knowledge. Consequently, they would have understood his initial principle to express a preference for the senses over the other faculties – especially over the intellect. (This might leave a residual puzzle as to how a situation could arise in which it would be possible to show this preference. We return to this later.)

The second question seems less tractable. How can we make sense of patent nonsense? (Or should we follow the authority of our teachers and simply ignore the word 'most'?) What could Descartes have meant by 'most true'? Since truth is something which we value and hence something for which we seek ('The *Search* for Truth'), it seems natural to link 'more true' and 'less true' with some kind of preference-order among judgments. How can we make sense of this idea? The French text suggests one possibility.[40] In place of '*maxime verum*', it reads '*le plus vray & assuré*' ('the most true and *certain*').[41] We might plausibly connect degrees of certainty with differences in the degrees to which various judgments are deeply embedded in our thinking, or conversely, to differences in our willingness to surrender them when confronted by counterarguments or contrary evidence. On this account, what I take to be 'most certain' is what I cling to most tenaciously,[42] what I am least willing to surrender in the face of contradiction (this could vary from person to person, or from time to time in each of our lives, or from generation to generation). Can we build a solid interpretation on this slender foundation?

The idea of preference-orders between pairs of judgments presupposes the possibility of being placed in a situation of having to make a *choice* between them. This is intelligible provided the two judgments are logically contrary to each other. That seems to make perfectly good sense if they are acquired from the same source; for example, I might glance at an apple and take it to be red, while a moment later it seems to me to be green, or I might be unable to grasp (touch) the dagger that I seem to see immediately before me. But how can this situation of logical conflict arise between judgments acquired from different faculties? They seem to be insulated from each other in virtue of having different subject-matter, just as a judgment about the sound of a trombone cannot clash with a judgment about its colour. How could a geometrical theorem clash with a singular sensory judgment? How could affirming one require anyone to deny the other? Surely this suggestion would have seemed as opaque to Descartes as it does to his twentieth-century readers.[43] He went on to explain the nature of each of the three faculties in such a way that the ranges of judgments that fall under them are disjoint. It is the task of the intellect alone to ascertain the truths of geometry, whereas it falls to the senses to settle directly[44] what are the sensible properties (colours, tastes, etc.) of corporeal substances.[45] So have we not reached an impasse in trying to make sense of making choices between judgments allocated to different faculties?

This may be the truth of the matter, but not how it first *appears* to be. 'Whatever is most true I acquired via the senses' seems to express a principle of dependence on, trust in, or reliance on the senses, and it is one of Descartes' main aims to encourage us to break this intellectual habit. He set out to end the tyranny of the senses (and the imagination) over our thinking. In his view, this is an obstacle to our coming to grasp clearly many common notions and basic principles of metaphysics.[46] Dependence on the senses generates a set of preconceptions or prejudices that are inconsistent with the metaphysical truths which are acquired from pure reason. Since everybody starts life totally immersed in the senses (indeed, in the body, i.e. the *internal* senses), we all tend to acquire the same set of prejudices and to mould all our later judgments to them. (These are 'the basic principles [plural!] on which all my former beliefs rested', i.e. the 'many preconceived opinions that keep us from knowledge of the truth'.[47] Later, when we are confronted with rigorous metaphysical reasoning, it *seems* to us to contradict some of these entrenched prejudices. For example, the conviction that there is no matter where nothing is perceived wars against the conclusion of a demonstration that space must be uniformly filled with matter. If, on reflection, I find that I have always resolved every such conflict by retaining the prejudice and rejecting the reasoning, then I judge that whatever I have taken to be most true is acquired from the senses (as opposed to what is acquired from the intellect). In this case, I discover that reliance on the senses is the most basic principle by which I have always led my intellectual life. On reflection I see now that I have systematically resolved all (apparent) conflicts in favour of 'the senses' rather than 'imagination' or 'intellect'. This has been the cash-value of my putting into practice the policy of relying on the senses *completely*.

Descartes thought that the natural process of intellectual maturation makes it highly probable that most educated people will operate on this same principle and hence be liable to the same prejudices.[48] It is these general preconceptions, 'accepted as true in my childhood', that are responsible for 'the highly doubtful nature of the whole edifice that I have subsequently *based on* them'. These prejudices have functioned as principles (plural!) in accumulating 'knowledge', and they are the primary target of the project of 'demolishing everything completely and starting again from the foundations'. The purpose of the reconstruction is to avoid relying too much[49] (or completely) on the senses.

There is no need to guess what Descartes had in mind. He listed and discussed a number of these 'preconceived opinions', and he pinpointed some of their pernicious influences. They all rest on identifying 'nothing' with 'nothing perceptible', e.g. 'no substance' with 'no perceptible substance', or 'no difference' with 'no perceptible difference'.

(1) *Denial of the existence of incorporeal substances* At best, knowing God or knowing what one's own soul is are treated as difficult;[50] at worst, one refers to the body all the notions one has concerning things related to the intellect,[51] and one's understanding of substance is limited to what is corporeal, imaginable, and capable of being perceived by the senses.[52]

(2) *Identification of intelligibility with imaginability*[53] Imagination can operate only on material provided by the senses. If possibility is limited to what can be imagined, understanding is fettered to the senses. In particular, the true nature of things is treated as capable of being perceived by the senses alone,[54] whereas in fact essence is perceived only by the intellect.[55]

(3) *Denial of the existence of imperceptible matter*[56] This prejudice conflicts with the pair of ideas that matter is infinitely divisible and that there

are thresholds for the operation of matter on the sense-organs of the external senses.[57] It clouds understanding of the principle, known by the Natural light, that matter is set in motion only by the impact of other moving mater.[58]

(4) *Denial that space is everywhere uniformly filled with matter* This takes the form of the prejudice that a vacuum is possible;[59] or more subtly, that different amounts of matter may occupy the same amount of space.[60]

(5) *Affirmation that sensations (sensible qualities) belong to the nature of matter* e.g. it is thought that colours constitute part of the essence of some corporeal substances.[61]

(6) *Affirmation that the soul must be the* principle *of movement in brutes*[62] Since self-movement and sense-perception are taken to be correlative powers in the Aristotelian tradition, this prejudice is linked to the view that brutes must see 'just as we do, i.e. being judging or thinking that they see'.[63] That view takes the soul as the principle of sentience in brutes.

(7) *The existence of real qualities,* e.g. gravity[64] This seems to be taken as equivalent to the idea that inanimate substances may have powers that cannot be fully explained solely in terms of their mechanical structures.

The target of withdrawing the intellect from the senses is, minimally, to dislodge these various preconceived opinions, which have gained a hold on our way of thinking.[65]

This interpretation of the initial principle (in Meditation I ¶3) makes maximal sense of the details of the text. It has additional merits. It eliminates problems about the identity of the speaker. Descartes need not assume any alien *persona*. He can speak in his own (earlier) voice as somebody who acknowledged all three traditional sources of knowledge, but who showed a (common, even natural) preference for one in cases of perceived conflict. At the same time, he thought that most readers could readily identify themselves with him in both these respects.

This interpretation also allows for continuity with what precedes and what follows the citation. Arithmetic and geometry were regarded as 'most certain' by Descartes even when he was 'immersed in the senses':[66] not because he held the senses to be the source of this knowledge,[67] but because he thought that there were no situations where these judgments came into conflict with any sense-based judgments,[68] and hence no occasions when they had to yield to other 'more true' judgments. Mathematical judgments were definitely among his 'earlier beliefs'; they were paradigms of *scientia*; and they were taken to be deliverances of pure reason. It is because they depend on the reliability of the intellect that they are appropriate targets of the metaphysical doubt about my nature which he aired in ¶9. Ignorance about my Creator does call into doubt *everything* that he previously took to be 'most certain'.[69]

By establishing the content of the initial principle, we have already made progress towards clarifying the antithetical principle: viz. the advice 'never to trust the senses *completely*'. This must mean something like this: 'do not (automatically?) resolve any conflict between the faculties in favour of the senses'.[70] But this raises a puzzle: how can this advice be seen to be justified by calling attention to the fact that the senses are known sometimes to have deceived us? Why, in this sense of 'complete trust', does occasional deception make complete trust irrational ('imprudent')?

The answer to this question requires clarification of Descartes' own understanding of the witness-metaphor. His reasoning turns on two points. First, he treated the senses as a *single* witness who stands in opposition to another witness, the intellect. His project is to ascertain the relative reliability of these two witnesses, not to differentiate among the bits of testimony of a single witness. Second, he invoked the principle that there is a reason to discount every single bit of testimony by any witness who is known not to be perfectly reliable.[71] This is a crude blanket downgrading of a whole corpus of testimony. But it is compatible with his making a point about preference-ordering among cognitive *faculties* by appealing to a general principle about the rational assessment of testimony.

An educated seventeenth-century reader would find this line of reasoning perfectly familiar and easy to follow, though it might seem opaque or speculative to twentieth-century philosophers. The reason for this is a dramatic shift in the conception of *logic* during the intervening three centuries. The Christian faith was held to rest squarely on acceptance of a body of historical knowledge: a narrative of the life and death of Jesus, the events of which occurred at a distant time in a distant place, and reports of miracles by various witnesses from many times and places. It was therefore the task of rational Christians to work out principles for assessing this very heterogeneous material and to show how to justify total reliance on the most central elements of this tradition. Consequently, Medieval and Renaissance logic texts included not only the theory of syllogistic inference, but also practical instruction in how to detect fallacies in everyday reasoning or disputation (e.g. the fallacy of many questions, the *fallacia accidentis*), and how to assess the strength of testimony.[72] The scope of logic was wide, and the range of unsound arguments (or 'fallacies') extended far beyond invalid syllogistic reasoning.[73]

Descartes used the witness-metaphor for a straightforward and transparent purpose: to invoke principles drawn from 'the logic of testimony'. In fact, two separate principles are applied in successive paragraphs.

In the first (¶3), the topic is what we have taken to be 'most true', i.e. with preferences as manifested in the resolution of conflicts. We are to envisage a case where, after collecting all available evidence and canvassing every argument ready to hand, the testimony of the senses clashes with the testimony of another faculty, say the intellect; the two witnesses contradict each other. Here, *ex hypothesi*, we have nothing further to appeal to. We have to make a decision about which judgment to affirm out of an antithetical pair, and we have nothing to guide us apart from the relative credibility of the two witnesses. If we follow the policy of using the senses to trump the intellect, we are in effect putting absolute trust in the senses. This is what it means 'to confide *completely*' in the senses. But this policy cannot be beyond rational criticism[74] once we acknowledge that the senses are not an unimpeachable witness, one whose testimony has *invariably* been borne out. At the very least, we must now concede that we need to investigate the credibility of the other witness (the intellect), and we must admit that there is an open possibility that the witness who contradicts the senses might prove the more reliable of the two. All of this is indisputably 'a matter of prudence'.[75] Since the senses are a witness whose character has been tarnished by instances of perjury, it is (morally) *irresponsible* 'to confide completely' in such a witness, i.e. to treat all of his testimony as unquestionable or 'beyond all reasonable doubt'.[76] This is one basic principle of the logic of testimony: both the absolute reliability of a single witness and the relative reliability of different witnesses are considerations relevant to accepting testimony.[77]

The next paragraph (¶4) continues the witness-metaphor:

> But even if the senses would perhaps sometimes deceive us about certain minute and very remote things, there are still many other things about which doubt is quite impossible [*de quibus dubitari plane non potest*], although they be derived from the senses – for example, that I am here, sitting by the fire, wearing a winter dressing-gown, holding this piece of paper in my hands, and so on.

Here Descartes introduced a complementary logical principle: viz. it is a fallacy to infer from the fact that a given witness is not absolutely reliable that *nothing* he says is to be accepted as *indubitable*. (To follow this policy rigorously would surely have the absurd consequence that we could learn virtually nothing at all 'through the senses', since every human instructor or authority has undoubtedly at some time or other made some false assertion.) Reason requires that one investigate the particular circumstances in which the testimony is made; for example, whether it would be wide open to contradiction by others if it were false, whether the witness lacked any obvious motive to lie, whether he was well placed to make the observations reported, etc. In some cases, the testimony of a less than perfect witness may carry strong probative force; indeed, it may settle something *conclusively* for another who is fully rational and responsible in framing his beliefs. (This principle was often illustrated with arguments for accepting without reservation certain reports of miracles.[78]) Here is another basic principle of the logic of testimony: external circumstances may put particular testimony of an imperfect witness outside the scope of what can be called into doubt by a rational person (somebody who is 'of sound mind' (*sanae mentis*), i.e. who exhibits '*le bon sens*').[79]

In ¶4 Descartes applied this logical principle to the testimony of the senses. Deception by the senses is most frequent in certain circumstances. Our visual judgments are known to be least dependable in respect of objects which are very small (e.g. neglecting air particles in judging that the space immediately surrounding our bodies is empty), or in the far distance (e.g. mistaking the shape of a distant tower). Particular external circumstances are known to distort sense-perceptions. (And there are others too, e.g. derangement of sense-organs, as in jaundice, or the interference of the media of perception, as in diffraction of light by water.) Nonetheless, in certain more favourable cases, doubt seems 'quite impossible'[80] in respect of sense-based judgments, viz. visual or tactile judgments about medium-size dry goods in our immediate vicinity. In the absence of special conditions, these judgments seem 'beyond question', 'unquestionable', or 'indubitable'. They are as *rationally* unshakeable as the testimony-based judgments 'Rome is a city in Italy' [*Romam esse*], 'the city of Troy once existed' [*Troiam fuisse*], 'The Pope dwells at Rome', 'Julius Caesar was a Roman emperor' and 'Luther had a great hand in the Reformation'.[81] (Hence, they are instances of 'moral certainty'[82] – things to be accepted by everybody of sound mind[83] and properly taken for granted in the conduct of life.[84]

The point of the double use of the witness-metaphor is first to formulate, then to refine, a challenge to the policy of giving absolute preference to the senses over the intellect.[85] Given a reader who has a mastery of the principles of the 'Art of Thinking', the metaphor makes perspicuous the structure of the interior dialogue of ¶¶3–4, and it leads smoothly into the doubt canvassed in ¶5. In fact, it unifies these three paragraphs.

The metaphor definitely does not inaugurate a search for some internal mark by which *individual* sense-experiences (or thoughts) can be known to be absolutely indubitable. In fact, it suggests that this investigation would be *obviously* futile or *patently* absurd. It would be comparable to trying to find a sensory characteristic of an isolated piece of testimony which would logically guarantee its truth. That would have to be an observable feature of speech which *could not* be imitated by a false witness!

The absurdity of such ideas rests on the commonplace that all testimony is subject to what scholastics called 'metaphysical doubt'.[86] It seems always conceivable that any corpus of testimony, however extensive and widely accepted by intelligent people, could be the product of a gigantic conspiracy. All of the 'witnesses' to the events of the life of Jesus and the acts of the apostles could conceivably have colluded in fabricating an historical narrative for the express purpose of misleading all future generations. Indeed, might not all of the testimony about anything outside my own direct experience be the product of a conspiracy to deceive *me* on the part of the whole of the rest of mankind? These metaphysical doubts, though impossible to annihilate, do not impugn the 'moral certainty' of maximally authoritative human testimony.[87] (They do not justify paranoia.) The argument that I might always be dreaming introduces a metaphysical doubt about the faculty of sense-perception[88] that is exactly parallel with this metaphysical doubt about testimony. So understood, it is not meant to challenge the moral certainty of well supported everyday singular sensory judgments.[89] On the contrary, somebody who ignored or contradicted these judgments in 'the conduct of life' would manifestly not be 'of sound mind'.[90] At the same time it would be mistaken to conclude that Descartes did not take the metaphysical doubt formulated in the Dream Argument to be a genuine doubt.[91] It is surely part of the corpus of 'powerful and well thought out reasons' (¶10) for calling into doubt all of his former opinions.

Acquaintance with scholastic treatment of the logic of testimony together with careful attention to the text of Meditation I makes clear the precise purpose, hence the *content*, of *Descartes'* witness-metaphor. It has a 'geometry' essentially different from the similar-sounding metaphors that modern philosophers read into his text. We have ourselves to blame if his metaphor fills our heads with alien ideas.

5

The proper interpretation of the witness-metaphor has important consequences for understanding the whole strategy and structure of the *Meditationes*. The ones I will mention briefly deserve fuller exploration than I can give here.

1) One controversial issue has been Descartes' 'foundationalism', and one aspect of that has been the interpretation of the term 'principle'. What did he mean by 'the basic principles on which all my former beliefs rested'? I have suggested that two rather different things fall into this category. First, there are a range of prejudices or preconceived opinions that have shaped or informed the whole edifice of his 'knowledge'. Second, there is a uniform characterisation of 'what I have accepted up till now as most true'. The second seems to underpin the first set of principles. Despite difference in degree of generality, both kinds of principle seem apparent in the resolution of conflict. In fact, the more general principle seems, as it were, to act via the less general prejudices: they are the proximate causes of my former beliefs, while it is the ultimate cause.

But why should we accept that his former beliefs *must* be integrated into such an hierarchical structure? Why is it impossible for me to find that my 'knowledge' rests on no principles whatever? Answers to these questions depend on how 'principles' are conceived to operate. If we imagine them to enter into inferences as explicit premisses, then there seems no reason why a rational thinker need have any principles; just as there is no necessity for a rational moral agent actually to deliberate by making deductions from supremely general maxims of action. On the other hand, we might take principles to be things that a rational thinker will acknowledge to be determinants of his own thinking when he reflects carefully and sensitively on the patterns of his own belief-formation. These may be difficult to discern; indeed, it may be impossible for him to recognize that his own thinking embodies a particular point of view or intellectual strategy, until he himself becomes aware of at least one alternative principle.[92] On the other hand, rationality is displayed in making choices, and choices must be made for good reasons, not arbitrarily or randomly. Hence, in so far as somebody is a *rational* thinker, he *must* be following some *principles* (of various degrees of generality), at least in the sense that his beliefs must exhibit an intelligible pattern. If they were chaotic, he *could not* be acquiring or preserving them by *free choice*.

Descartes' conception of intellectual principles seems closely parallel to Aristotle's conception of practical principles. Just as every free, rational moral agent[93] must organise his life around one of the three ends: pleasure, honour, or moral virtue,[94] so too every free, responsible thinker must order his intellectual life around the policy of giving pre-eminence to one of the three faculties: senses, imagination and intellect. (Order is the necessary condition of rationality.) This conception would call for further clarification and support, perhaps for modification or refinement. But it is certainly not refuted by the criticism that human knowledge need not be organized into an axiomatic system in which the 'foundations' provide logical support for the whole body of 'theorems'.

2) The original policy of trusting *absolutely* in the senses is to be countered in three stages. At first we must learn to 'withdraw our minds from the senses', especially by practicing the discipline of suspending judgment on all singular sense-based thoughts. Later we must carry out a more difficult programme: examining the prejudices or preconceived opinions acquired in our youth for the purpose of weeding out any that we can now call into doubt. Finally, it seems, we should put into practice the contrary policy of trusting *absolutely* in the intellect for the purpose of acquiring genuine knowledge (*scientia*) about 'the nature of things', i.e. we should systematically prefer the intellect to the faculties of sense and imagination as sources of such knowledge.[95] What is 'most true' (or even 'most certain' (*plane certum, certissimum*)) is what is acquired from pure reason.

This general programme of intellectual reformation depends for its justification on demonstrating that the intellect is a more reliable *witness* than the senses. For, if that can be proved, then it is rational (logical and morally responsible) to prefer the testimony of the intellect to the testimony of the senses whenever there is conflict. One of Descartes' principal goals is to vindicate the thesis that reason is 'a reliable instrument [which] is God's gift to us'.[96] Provided we use this *faculty* properly, it *cannot* lead us into error. This principle is summarised in the thesis 'whatever we clearly and distinctly perceive is true'. This is equivalent to the claim that the intellect is a perfectly reliable or absolutely unimpeachable witness. Any mistaken judgments that arise from reasoning wholly independent of the senses and the imagination must be blamed on our *misuse* of the faculty of reason. (Meditation IV is a theodicy devoted to vindicating this claim.) By contrast, we know that there really are cases where we have been deceived by the senses (and even the imagination). So the intellect can be proved to be the most reliable witness of the three faculties which are the sources of all knowledge.[97]

3) The principle 'whatever we clearly and distinctly perceive is true' is comparable to the original principle 'whatever is most true is acquired via the senses'. Both express preferences between the three faculties of the understanding.[98] Neither is intended to provide what modern commentators call 'a criterion of truth'.[99] Just as there can be no sensory property of a bit of testimony that logically guarantees its truth, so too there can be no (intelligible) property of a thought that logically guarantees its truth.[100] *A fortiori*, 'being clearly and distinctly perceived' cannot be Descartes' label for such a chimerical property, and the phrase should not be translated 'self-evident'.[101] On the contrary, he held that the distinction between appearance and reality applies to 'clear and distinct perception'. In other words, it makes sense for us to be mistaken in judging that we do clearly and distinctly perceive a particular thought.[102] The principle that Descartes formulated is meant to express his validation of the *faculty* of reason (the intellect). It is somewhat similar to a formal proof that a particular system of inference-rules for the predicate calculus is both sound and complete; or to a philosophical argument that makes clear the rationality of the accepted canons of inductive reasoning. It is as absurd to ground the verdict that a particular judgment is true on the reliability of the faculty of reason as it would be to argue that a particular piece of reasoning is beyond criticism on the ground that it is rational to reason inductively. To say that a faculty is perfectly reliable justifies any particular operation of the faculty only on the supposition that this operation is carried out *correctly*.[103]

An immediate corollary of this point is that the principle 'whatever is clearly and distinctly perceived is true' *cannot* be used as a premiss (or even as a rule of inference) in a demonstration of the truth of particular judgments.[104] The problem of the so-called 'Cartesian Circle' then completely disappears;[105] there is no room for a simple *petitio principii*.

4) From the original principle 'whatever is most true is acquired via the senses', we might extract two implications: first, that there is a wide range of judgments about which the three main faculties deliver conflicting testimony and, second, that these conflicts are decided uniformly in favour of the senses and against the intellect. Consequently, we might expect Descartes simply to argue for reversing this rank-order among the faculties. But this is not his predominant strategy.[106] Instead of resolving conflicts in favour of reason, he dissolved most of the apparent conflicts by clarifying the jurisdiction of each of the three faculties. In most cases he tried to show that the problem-generating testimony of the senses (and

the imagination) involves their laying claim to settle matters that fall outside their jurisdiction.[107] Once this is acknowledged, reason is the only qualified witness in all these cases. Remaining after this treatment are a few genuine conflicts,[108] mostly in 'physics' or natural science, and there Descartes offered special arguments for resolving these questions in favour of reason.[109] His mechanics has its foundations in pure reason: in axioms known by the Natural light (e.g. that matter can be set in motion only by the impact of other moving matter) and in clearly and distinctly perceived absolute certainties (e.g. that there are imperceptible particles and that space is completely and uniformly filled with matter).[110]

The main programme is to establish the narrow jurisdiction of the senses, the comprehensive scope of the intellect, and the absolute distinction between their proper objects.[111] In Descartes' view, there are three main kinds of judgment which fall under the intellect alone: viz. judgments about finite incorporeal substances and their modes,[112] those about the essence of corporeal substances, and those about God (or infinite incorporeal substance). In this order, these judgments form the subject matter discussed in Meditations II–III.

First, the only judgments which cannot be called into doubt by the metaphysical doubts of Meditation I are those about some of the 'operations' of my soul. By *conscientia* (the power of the soul to gain knowledge of itself and its own operations), I can be certain that I am a thinking thing. This knowledge lies essentially outside the scope of the senses (even the internal senses), whose objects can be only corporeal things and their properties. Indeed, *conscientia* is a power of the intellect,[113] and the knowledge gained by reflection on one's own modes of thinking is acquired from reason alone.[114]

Second, Descartes argued that all knowledge of the nature (or essence) of particular corporeal substances ('this wax') is gained not from the senses, but from reason ('the faculty of judgment').[115]

Finally, he demonstrated that the only substance of whose existence I can be certain from inspecting the thoughts that I find within me is God, an infinite incorporeal substance whose existence and attributes cannot be ascertained by the senses. In this way Descartes argued that the foundations of true knowledge (*scientia*), as well as all knowledge of the *nature* of things, lie outside the jurisdiction of the senses.

Dissolving the apparent conflict between reason and the senses is a unifying theme in Meditations I–III. Twentieth-century Anglo-American commentators have failed to appreciate this point, instead taking the overall aim to be an attempt to ground empirical knowledge in immediate private experience. This seems an exemplary case of genre-misidentification.

5) The whole of the *Meditationes* can be viewed as a debate about the absolute and relative merits of the cognitive faculties of the soul. On the one hand, sense and imagination are jointly demoted in rank. They are

not cashiered, but they are to be confined within their proper jurisdictions. On the other hand, reason is elevated in status. It alone is competent to give knowledge of God, rational souls, moral principles, and the natures of things. These observations are supplemented by arguments eliminating the metaphysical doubts raised in Meditation I about all three of the faculties. Reason is shown to be perfectly reliable if properly used (Meditation IV), while the senses reliably guarantee the existence of particular material things and knowledge whether particular things can benefit or harm us (Meditation VI). As is to be expected, 'our [God-given!] Nature' as union of body and soul is perfect of its kind. Each faculty has its place in our lives, and provided we make proper use of it within its jurisdiction, each makes an important contribution to human welfare. No part of the *Meditationes* is extraneous to Descartes' demonstration of this comprehensive conclusion. Far from being an irrelevant discussion of a version of the problem of evil, Meditation IV has the pivotal role of demonstrating that the intellect is a completely reliable witness whenever it clearly delivers testimony.

6

Most analytic philosophers now seem sceptical about the value of Faculty-Speak,[116] and many would see little value in the project of trying to determine the relative reliability of different faculties as sources of knowledge.[117] But this is no excuse for failing to take note of the prominence of this concern in philosophical writings from the sixteenth through the eighteenth centuries, or for neglecting its role in determining the overall structure of the *Meditationes*.

In a nutshell, the witness-metaphor is a seed from which the whole of the text develops as a mature plant. It *prefigures* the argument to come. The author of the *Meditationes* is someone even less congenial to us than the figure called 'the Founder of Modern Philosophy' that we have all been educated to loathe. Hence too, he is someone even more challenging and interesting to study closely. We need to overcome some of our own philosophical prejudices or preconceptions if we are to *engage* properly with *his* thinking.

Notes

1 Meditation I¶3 AT vii. 18. Translations are my own, and all italics in these citations have been added.

2 Note Francisco Suárez' title of Book II of his commentary on *De Anima*: 'De Potentiis Cognoscitivis in Communi' (*Opera* (Mainz, 1622) ii-B. 102). These are later subdivided into *potentiae sensitivae* and *intellectivae*, and they are contrasted with other powers of the soul (*appetitivae ac loco movendi*).

3 Though Descartes criticised Lord Herbert of Cherbury for holding the principle that 'we have as many faculties as there are different objects of know-

ledge', nevertheless 'it is a useful practice not to accept any belief without considering on what warrant or for what cause one accepts it; and this comes to the same thing as his advice always to consider what faculty one is using'. (AT ii. 598).

4 Arguably the two faculties sense and imagination are not here differentiated, though elsewhere (Med II ¶¶8–9) they are. This seems to explain why calling sense-perception into doubt (Med I ¶6 and ¶12) is later taken to call into doubt *past-tense* judgments about the existence and perceptible properties of corporeal things (Med II ¶2), even though memory is an exercise of the imagination. These two faculties are traditionally taken as jointly the source of all singular knowledge about corporeal things. Here they are lumped together as 'the senses' for the purpose of drawing a contrast with the intellect.

5 It seems to be a demand of rationality that different *potentiae* of the rational soul be compared with each other and ordered by their relative values. Consequently, Suárez (Vol ii-B) completed his examination of the five external senses with this topic: '*De comparatione quinque sensuum inter se . . . Perfectissimus sensus est visus, deinde auditus, postea olfactus, deinde gustus, ultimo tactus.*' (158b). Various proofs are given: e.g. sight is most perfect because it has the noblest object [*lux enim est nobilissima qualitas inter sensibiles*], the noblest way of being affected by its object (viz. at the greatest distance), the widest and discriminating knowledge of common sensibles, and the most perfect organ. This is followed by a comparison of the five senses '*secundum utilitatem ad scientiam*': '*In homine imperfectissimus est oderatus, deinde gustus, alij vero tres mutuo se excedunt, simpliciter tamen excedit visus.*' (159b).

6 Their number was controversial. Aquinas distinguished four, whereas Suárez argued that there was only one (ii-B. 164a: '*Probabilius videtur sensum interiorem unum tantum esse realiter*') and added that the different terms used by Aquinas ('*sensus communis*', '*phantasia*', etc.) stand for different perfections of a single sense ('*solumque significant diversas perfectiones eiusdem sensus in homine*').

7 Cf. AT xi. 163–5; *Principia* IV, arts.190–5; *Passions* I, §§ 23–4.

8 *Principia* I, art. 71.

9 AT vii. 76–7.

10 e.g. AT xi. 202.

11 *Conscientia* is defined as the power of the rational soul to apprehend itself and its own operations [*scientia sui et suarum operationum*]. This standard definition is cited by A. Arnauld, *On True and False Ideas*, ch. 2. Aquinas denies that *conscientia* is a sensitive power (*Summa contra Gentiles*, IV.11), and Suárez lists it among the powers of the intellect (ii-B. 152b).

12 AT x. 496. Compare Locke's division of 'probable knowledge' into judgments grounded in one's own sense-experience and those grounded in the testimony of others about matters that fall under the senses (e.g. historical narratives and reports of the results of scientific experiments: *Essay* IV xv.

13 This corpus of judgments is the main focus of Locke's discussion of 'Probability'. [*Essay* IV. xv. 5–6].

14 There is evidence that Descartes preferred this reading: 'The objection cannot be made here that [the original principle quoted from Meditation I] leaves out the common principles and ideas of God and of ourselves, which were never in the senses. . . . For . . . I acquired these . . . through the senses.' (AT v. 146).

15 Contrast this remark: '. . . the philosophical novice with whose voice he speaks in Meditation I is as yet unaware that there are non-sensory sources of knowledge.' (H. Frankfurt, *Dreamers, Demons and Madmen* (Indianapolis, 1970), 32). Compare: '. . . throughout [the First] Meditation, Descartes is examining beliefs based on the senses.' (G. Dicker, *Descartes* (Oxford, 1993), 22).

16 This claim is central to Frankfurt's reading of the whole of Meditations I-II.

17 If we accept Descartes' gloss on 'through the senses' as making reference to what is learned from testimony or the authority of teachers, the hapless ingenue will also have to follow the policy of accepting everything that he is told without question.

18 Kenny gives this paraphrase: '. . . and it is imprudent to trust where one has once been deceived.' (*Descartes* (New York, 1968, 15). Cottingham gives a similar paraphrase of this first phase of doubt: 'Descartes rejects the testimony of the senses.' (*Descartes* (Oxford, 1986), 29). This interpretation dates back to Le Grand: 'Since all our senses are fallacious, and we are frequently deceived by them, *common sense* advises that we should not put too much trust in them, nay, that we should suspect falsehood in *everything* they represent; for it is imprudence and temerity to trust to those who have but once deceived us; and, if they err *at any time*, they may be believed *always* to err.' (*Logic*, quoted by Thomas Reid, *Essays on the Intellectual Powers of Man* (Edinburgh, 1863), 334b).

19 The policy is one response to cases of deception by the senses (e.g. judging that an oar partly immersed in water is bent). Cicero attributed it to Epicurus. He suggested that any attempts to avoid its absurdity led to further absurdity [*Academica* II. xxv (79–80)]. [Epicurus claims that] '*si unus sensus semel in vita mentitus esse, nulli umquam esse credendum. . . .*'. Accordingly, Timagoras the Epicurean denies that he has ever really *seen* two little flames coming from the lamp when he has screwed up his eyes; '*opinionis enim mendacium, non oculorum*'. As if the question were *quid sit, non quid videatur*! (Compare II. xxxi (100): Anaxagoras denied that water even *appeared to him* [*sibi videri*] to be white, because he knew that it was solidified water and that water is black.)

20 This line of interpretation is developed with much subtlety by Frankfurt (40–53), and in a simplified form by Dicker (op. cit., 17–9).

21 Contrary to Descartes' explicit denial of this principle (AT vii. 438–9).

22 Licensing us to read 'principles' in ¶2 to mean 'opinions' (M. Wilson, *Descartes* (London, 1978), 5–6).

23 Cf. Frankfurt, op. cit., 32: '. . . the philosophical novice with whose voice he speaks in Meditation I . . .'.

24 ¶¶8–10.

25 The 'matters which we previously regarded as most certain [*maxime certa*]' included mathematics (*Princ* I §5). Cf. AT vii. 65.

26 AT v. 146.

27 There is scope for loosening the requirement of naivety, at least to some extent. We might take the speaker to be somebody who has good common sense but is *philosophically* unsophisticated – '. . . the man who is only just beginning to *philosophize* . . .' (AT v. 146) – or to be an exponent of the empiricist doctrine that every simple idea must be derived from a sense-impression. Cf. Frankfurt, op. cit., who presents him as a Humean empiricist (70–1).

28 G. Ryle, *Dilemmas* (Cambridge, 1954), 99.

29 Ibid., 99.

30 This idea is the foundation for Reid's whole discussion of 'fallacies of the senses' (op. cit., 335–9).

31 Wittgenstein, *Philosophical Investigations*, §295. One might use the analogy as an invitation to elaborate a naturalistic explanation of human cognition. Sense-perception must be information-processing. The reception of sensory information is apparent in animals: ergo there is 'animal cognition'! (G Evans, *The Varieties of Reference* (Oxford, 1982) 123n, 124; A. Kenny, *The Metaphysics of Mind* (Oxford, 1989), 106–12). Sense-experiences are inner states of organisms which are caused by states in the objects perceived and which in turn

cause appropriate responses, especially movements of flight or pursuit. Though Descartes is alleged to have begun in the *Regulae* with this promising line of investigation into animal cognition, he is claimed to have been diverted from it later by extraneous metaphysical and theological concerns. (S. Gaukroger, *Descartes: an intellectual biography* (Oxford, 1995), 161–7, 276–90).

32 AT vii. 29.

33 For detailed clarification of this conception see G. Baker and K.J. Morris, *Descartes' Dualism* (London, 1996), 72–84.

34 AT vii. 96.

35 In fact, it is doubtful there was any other approach to the question of judging the probability of a report or prediction until late in the seventeenth century. See the article by L. Daston on 'Probability and Evidence', in D. Garber and M. Ayers, eds., *The Cambridge History of Seventeenth-century Philosophy* (Cambridge, 1998), 1108–44.

36 Meditation II (¶¶11–6); Meditation III (¶11); *Principia* I, arts. 71–3.

37 From Descartes' point of view, the modern term 'empirical proposition' embodies a confusion; it conflates *conscientia* with *sense*-perception in taking sense-experience to be the sole arbiter of truth and falsity of singular contingent statements, and it thereby misrepresents the jurisdictions of both reason and the senses.

38 So one may, on the one hand, find it in Aristotle (*Nich. Ethics* 1094a1–3), or, on the other hand, exonerate Descartes from this charge by distinguishing two 'waves of doubt' in Meditation I ('the Universal Possibility of Doubt' and 'the Possibility of Universal Doubt').

39 I use the phrase 'via the senses' to avoid having to attend to the distinction between 'from the senses' and 'through the senses'.

40 AT ix-B. 14.

41 The Latin text of *Principia* makes use of the phrases 'maxime certa' and 'certissima', and the French of the expression 'tres-certain' (*Principia* I, arts. 2, 5: AT viii. 5–6, ix-B. 25–6).

42 This seems to be the status of the prejudices that the mind has taken to be *most true* and evident since youth (*pro verissimis evidentissimisque admisit*); they are used to trump later experience (*Principia* I. art. 71).

43 Aristotelians had to start from the principle that singular judgments alone fall under the juristiction of the senses, while universal judgments alone fall within the competence of the intellect. (Suárez, ii-B, 172b: '*Aristoteles . . . constituit differentiam inter intellectum, & sensum, quod sensus sit singularium, intellectus universalium.*')

44 I.e. without inference; otherwise 'the faculty of judgment' is involved, as when we judge that there are men crossing the square in the rain underneath the hats and cloaks which are alone visible from an upper window (cf. AT vii. 31–2).

45 Though Descartes denies that colours, tastes, etc. belong to the *nature* or *essence* of corporeal things, he does not deny that they are *accidents* of these substances. (Arguing for this interpretation lies outside the scope of this chapter.)

46 AT vii. 131, 157, 162, 231, ix-A. 204–6.

47 *Principia* I, art. 1.

48 *Principia* I, arts. 71–3.

49 *Principia* I, art. 4: '*nimis fidere*'.

50 AT vi. 37.

51 AT vii. 441.

52 *Principia* I, art. 73; cf AT vii. 441.

53 AT vi. 37; AT vii. 441; *Pr* I art. 73.
54 Cf. *Principia* I, art. 73.
55 AT vii. 34.
56 *Principia* II, art. 17; XI, arts. 17, 21.
57 *Principia* IV, art. 201.
58 AT xi. 38; *Principia* II, art. 37.
59 *Principia* II, art. 18.
60 AT xi. 17, 21; *Principia* I, arts. 17, 71.
61 *Principia* I, arts. 48, 67, 71.
62 AT v. 275–6; AT vii. 229–31, 351, 356, 359, 427. The term 'principle' here echoes Aristotle (*De Anima* 415b8: 'the soul is the cause and principle [*aitia kai* arche] of the living body').
63 AT i. 413.
64 AT vii. 441–2.
65 *Principia* I, arts. 1, 50, 67, 71; cf AT i. 413, vii. 231.
66 Meditation V ¶6; *Principia* I, art. 5; AT vii. 445.
67 Cf. Frankfurt, op. cit., 61–7.
68 AT vii. 156; cf. AT iii. 695.
69 This does not amount to calling *everything* into doubt (AT vii. 206, 580); rather to calling into doubt all judgments about the existence or essence of *corporeal things*.
70 Or perhaps: 'do not resolve any conflict between reason and sense (+imagination) against reason'.
71 Though one path to knowledge is experience, 'the other path is the authority of *persons worthy of credence* who assure us that a certain thing exists, though we know nothing about it'. (Arnauld and Nicole, *Logic or the Art of Thinking* (Indianapolis, 1964), Pt. IV, ch. 12 (my italics))
72 In the course of other discussions, Descartes appealed quite casually to such logical principles, e.g. AT vii. 424.
73 Arnauld and Nicole, *Logic* Part IV, ch. 12–15; Watts *Logicke, or the Right Use of Reason* (Halifax, 1847), II.v.5–6; cf. Locke *Essay* IV. xv 'Of probability'. (This material was later displaced from logic texts by analyses of the principles of inductive reasoning; e.g. Book III of J.S. Mill's *A System of Logic.*)
74 It is a clear case of trusting *too much* (*Principia* I art. 5).
75 The term '*prudentia*' may well be used by Descartes to mean 'knowledge of *moral* right and wrong in action', as in Cicero; hence not 'prudence' (or 'common sense') in the *modern* sense, which excludes anything moral from consideration. Compare: '. . . *dico prudentiam, si sumatur pro actu ipso intellectus, consistere in recto judicio circa actionem exercendam, quo scilicet quis judicat, juxta regulas rationis hic & nunc debet haec res tali modo fieri.*' [Suárez, *Opera* v. 605, n.10] (These important issues cannot be further investigated here.)
76 'If a person is known to lie occasionally, it is not reasonable to accept something *simply* on the grounds that he testifies to it.' (Frankfurt, op. cit., 35) This is one of the standard 'Rules of Judgment in Matters of human Testimony': namely, 'Consider whether the Narrator be *honest* and *faithful*, as well as skillful . . . In short, whether there be no *Occasion of Suspicion* concerning his report.' (Watts, *Logicke*, III.v.5).
77 'The integrity' of the witness is one of six independent factors listed by Locke (*Essay*, IV. xv. 4).
78 Arnauld and Nicole, *Logic*, Pt. IV, ch. 14.
79 'Even a man who lies may be trustworthy concerning some things.' (Frankfurt, 35) This is a weak formulation of another traditional principle: even though 'we know nothing about the Antipodes except by human faith, we would have to be *insane* not to believe in them. Similarly we would have to

have *lost all sense* to wonder whether Caesar, Pompey, Cicero or Virgil ever existed, or whether they were only imaginary characters. . . .' (Arnauld and Nicole, *Logic*, Pt. IV, ch. 12 (my emphasis)).

80 Not 'psychologically impossible', but 'patently irrational and morally irresponsible.' (Discussion of this issue must be deferred to another occasion.)

81 The first two examples of moral certainty are repeated *ad nauseam* in scholastic treatises (the first is incorporated into *Princ* IV art. 198); the other three come from Watts, *Logicke*, II. v. 5.

82 *Discours* IV: AT vi. 38. This terminology belongs to a scholastic doctrine of different 'degrees of certainty' (*gradus certitudinis* (cf AT vii. 66)) which is not understood at all by modern philosophers. Though important for understanding the *Meditationes*, it cannot be explained here.

83 *Meditationes*, Synopsis: AT vii. 16.

84 *Principia* IV, art. 205. Arnauld and Nicole, *Logic*, Pt. IV ch. 13. 'The conduct of life' includes moral judgments, including choices of how to act, on which depend the agent's salvation or eternal damnation.

85 The witness-metaphor plays a substantive role in Descartes' thought, uniting the critical assessment of sense-perception, memory, etc. with the rational treatment of testimony. Though the concept of 'moral certainty' seems to be most at home in the discussion of historical and geographical propositions whose acceptance turns on others' testimony, it is applied without any special explanation to all singular judgments about corporeal substances, especially to judgments about the sensible properties of medium-size material things observed in favourable conditions. The concept of 'le bon sens' thereby also takes on a wide range of application.

86 It is quite mistaken to treat the term 'metaphysical' in this scholastic usage as a privative adjective, say as being equivalent to 'chimerical'. (Cf. Wilson, op. cit., 10–1.)

87 Things known by 'human faith' (*certa fidei humanae*). These are certainties, not mere probabilities.

88 AT vii. 172.

89 AT vi. 37–8.

90 In *this* sense, his behaviour would be 'laughable' or 'ridiculous' or 'extravagant'; i.e. inconsistent with manifesting 'le bon sens' (cf. AT vi. 38; vii. 351, 460, 475). It would be 'completely irrational' (Arnauld and Nicole, *Logic*, Pt. IV, ch. 13).

91 Still less reason to conclude that *he* was confused about the relation of doubt to action (Wilson, op. cit., 46). Modern neglect of the scholastic distinction between moral and metaphysical doubt is what is responsible for making his position seem unintelligible.

92 Wittgenstein made this observation about the system of principles that form our world-picture (*Weltbild*) or frame of reference. L. Wittgenstein, *On Certainty* (Oxford, 1969), §§83, 141–2, 144, 152, 162, 209–11, 273–4, 292, 336, 378.

93 A person capable of rational choice ('*prohairesis*').

94 Aristotle, *Nich. Ethics* 1095b14–6a10.

95 Including what is known 'through the senses', i.e. from testimony. Cf. Arnauld and Nicole, *Logic*, Pt. IV ch. 13.

96 AT v. 148.

97 Descartes' project has affinities with the scholastic practice of seeking to rank the powers (*potentiae*) of the soul in respect of 'degrees of perfection (*perfectio, nobilitas*)' (e.g. Suárez ii-B 206a: '*Quaenam sit perfectior potentia, intellectus ne, an voluntas.*'). Perhaps even closer affinities with the project of ranking the five external senses relative to each other '*secundum utilitatem ad scientiam*' (Suárez ii-B 159b).

98 Hence the first is concerned with the intellect as opposed to the senses (and the imagination). Achieving clear and distinct perception requires intellectual *activity* (or exertion) in working out that one thought is distinct from all other thoughts with which it might be confused.

99 Williams sets off in the wrong direction from the very beginning in claiming that Descartes' starting point is the question how an individual person can be certain of the truth of any individual proposition. ('Rationalism' in P. Edwards *Encyclopedia of Philosophy*, Vol. 7 p.72[b].)

100 Nothing parallel to this thesis: a tautology is a sentence whose truth can be demonstrated from the *logical* properties of its *symbols* (L. Wittgenstein, *Tractatus Logico-Philosophicus*, 6.126).

101 At least if 'self-evident' is understood in this familiar sense: 'The highest degree of self-evidence is a really infallible guarantee of truth' [B. Russell, *Problems of Philosophy* (London, 1912), 118]. Descartes is commonly credited with the idea that the foundations of knowledge must be self-evident judgments: 'to the deceptiveness of the senses will ultimately be opposed the absolute *data* of certain deliverances of reason'. (Wilson, op. cit., 9).

102 The standards for making such assessment are perfectly objective, e.g. whether the proof of a geometrical proposition contains a fallacious step. (This point needs more argument than I can give here.)

103 It is then crucial to clarify on what grounds that supplementary premiss may be called into doubt.

104 In this respect, it might be compared to the 'Principle of the Uniformity of Nature'.

105 Like the problem of justifying induction.

106 This would amount to blasphemy! '. . . it seems to be a very unfavourable account of the workmanship of the Supreme Being, to think that he has given us one faculty to deceive us – to wit, our senses; and another faculty – to wit, our reason – to detect the fallacy.' (Thomas Reid, *Essay on the Intellectual Powers of Man*, II. xxii).

107 Malebranche put the point with some nice irony: 'Men . . . trust their eyes in judging not only about visible objects but also about objects that are invisible. As soon as they do not see certain things, they conclude that they do not exist, thus attributing to sight powers of penetration to some extent infinite.' (*The Search after Truth*, I.vi.2).

108 Indeed, few instances where the same judgment may be traced to different sources of knowledge. There is scope for disagreement about this too. According to Watts, 'that the whole is bigger than a part is known by our Senses, and it is known by the Self-Evidence of the thing to our Mind [Intelligence]' (*Logicke* II. ii. 9); but Descartes held that quantities are not sensible properties of corporeal things (*Principia* I art. 55), while Russell much later argued that this mereological 'axiom' is a paradigm of deception by reason, demonstrating the unreliability of self-evidence (B. Russell, *Our Knowledge of the External World* (Chicago, 1914), 194–6).

109 To a first approximation. He also argued that mechanics is concerned exclusively with quantities (modes of extension). By contrast with colours, tastes, etc. ('sensations'), these properties of corporeal substances are ascertained by reason, not by the senses. Hence even mechanics is put outside the jurisdiction of the senses! (In this respect, Descartes followed the scholastic tradition of allocating all *scientia* of the *nature* of material things to the intellect.)

110 It is a serious misunderstanding to conflate things known by the Natural Light with judgments that have the property of being 'completely certain' [*plane certum*]. But I cannot pursue this issue here.

111 We must eradicate the habit of confusing 'intellectual things' and 'coporeal

things' (AT vii. 131). (What Aristotle called '*ta noeta*' and '*ta aistheta*'; and scholastics distinguished as '*universalia*' or '*generalia*' from '*particularia*', '*singularia*', or '*individua*'.)

112 These include moral laws (which are binding on all rational creatures) and judgments about virtue, vice, freedom, responsibility, obligation, etc. (This important point is regularly neglected in treatments of Descartes' conception of the 'mind'.)

113 To the extent that 'Cartesian introspection' is identified with *conscientia*, it is a fundamental distortion of Descartes' position to take introspection to be 'inner *sense*' or a species of *sense-perception* whose objects are mental events, states, etc. (*Pace* standard accounts of 'Cartesian Dualism'.) This obliterates the crucial distinction between *conscientia* and the internal senses, and it misrepresents the boundary between the faculties of sense and intellect. These points are recapitulated by Suárez. '[*Dicendum est*] *conscientiae nomen juxta frequentiorem usum significare aliquid pertinens ad* intellectum'; also '[*notandum est*] *conscientiam esse actuale & practicum* judicium intellectus *discernentis de rebus agendis inter bonum & malum, turpe & honestum, praeceptum vel prohibitum.*' (ii-C. 314 n.3 and 315 n.5 (italics added)) He also offered proofs that human capacity to reflect on the operation of the senses cannot itself be a form of sense-perception [potentia sensitiva] (ii-B. 129a), and that only the intellect has the power to know itself and its own operations (cf ii-B. 180a). Compare Watts: under 'Evidence of *Sense*' he included, in addition to knowledge of material things gained through the use of the five external senses, also all knowledge 'which is deriv'd from the inward Sensations and Appetites of Hunger, Thirst, Ease, Pleasure, Pain, Weariness, Rest, &c. and all those Things which belong to the *Body*'. With this corpus of knowledge he contrasted what is known through 'an *inward Consciousness*, which may be call'd a sort of . . . *spiritual* Sensation of what passes in the *Mind*'. (*Logicke* II. ii. 9: his italics suppressed, mine added)

114 In particular, knowledge that I am a thinking *thing* or *substance* depends on solely on the reasoning from the metaphysical principle that a mode must inhere in a substance. In respect of this argument, it is irrelevant to remark that I cannot 'catch sight of (or observe) myself' while I am thinking (cf. Hume, *Treatise*, I. iv. 6). Indeed, Descartes stressed that the idea of the rational soul is one that cannot be derived from *sense*-experience.

115 This is a modified version of the common scholastic doctrine that *essence* can be apprehended by reason alone.

116 Though Frege and Russell were still strongly influenced by this conception. For example, Frege grounded the axioms of logic in 'a logical source of knowledge' (*Posthumous Writings* (Oxford, 1979), 267–7).

117 Cf. G. Warnock's entry under 'reason' in P. Edwards, ed., *Encyclopedia of Philosophy*: talk of the power of reason is unclear, so it is better to transform the question 'What can reason do?' into specific questions about the capacities of persons to whom reason is attributed. (Vol. 7 83b-84a).

25 Descartes' naturalism about the mental

Gary Hatfield

Descartes' reputation as the arch dualist who banished mind from nature seems secure. He conceived mind and body as distinct substances, unified the domain of mind under the rubric of consciousness, and bequeathed the problem of mind–body interaction to his followers. He rendered sensory qualities peculiarly mental and subjective by excluding them from body qua extended substance, relegating them to mind as what were later called secondary qualities. The ontological divide he established between mind and matter seemingly removed mind from the province of natural science.

Although each of these assertions about Descartes' legacy contains a grain of truth, all but the bare assertion of Descartes' substance dualism and the resultant problem of interaction are incomplete or distorting. To help round out the picture, I will advance two theses involving Descartes and the mind. The first concerns Descartes' conception of mental faculties, particularly the intellect. As I read the *Meditationes*, a fundamental aim of that work is to make the reader aware of the deliverances of the pure intellect, perhaps for the first time. Descartes' project is to alter the reader's Aristotelian beliefs about the faculty of the intellect and its relation to the senses, while at the same time coaxing her to use the pure intellect to perceive the first truths of metaphysics. His anti-Aristotelian understanding of the power of pure intellect undergirds his attempted revolution in metaphysics and physics.

The second thesis pertains to Descartes' naturalism about the mind. Descartes is seen as having excluded mind from nature, thereby deanimating (literally, 'de-souling') the physical world and making it safe for a full-scale mechanistic physics. As E.A. Burtt, Wilfrid Sellars and Margaret Wilson would have it, Descartes relieved physics of any mentalistic refuse by sweeping sensations and other conscious states into the trash can of the mind. In the interest of physical science, Burtt says, Descartes 'insisted that secondary qualities must be stripped from extended matter, even pains must be taken out of our limbs, and all but the mathematical qualities bestowed on the soul'. This attitude effectively makes the mind into 'a convenient receptacle for the chips and whittlings of science, rather than a possible object of scientific knowledge'.[1] In contrast, I argue that Descartes included (at least some functions and states of) mind as part of nature, that despite his dualism he continued an established tradition of treating the operations of the senses as open to empirical investigation, and that in virtue of his dualism he initiated a new line of thought leading to the search for specifically psychophysical laws, that is, laws linking non-mental bodily states to states of mind.[2] The precise senses in which Descartes did and did not include mind under the rubric nature is problematic; but he did use language suggesting that even the intellect is a natural constituent of the human being, as when he ascribed intellectual cognitions to 'the natural light'.

These two themes taken together may initially seem to lead Descartes into yet further difficulties than those usually associated with his philosophy. According to the first theme, Descartes staked the normative foundation of his metaphysics – its warrant or justification – on appeals to freshly uncovered perceptions of pure intellect. By some lights, such an appeal to a mental faculty may look like an instance of psychologism – that is, of the allegedly fallacious attempt to ground knowledge claims on descriptions of states of mind, now including purely intellectual states of mind. And if Descartes did in fact regard even the intellect as in some sense natural, that seems to confirm the charge. But I deny that Descartes was guilty of psychologism in the nineteenth- and twentieth-century sense of that term.[3] His reliance on a theory of mental faculties was not an instance of appealing to naturalistic psychology for epistemological purposes. To see why, we will need to consider his conception of mental faculties and their powers, and to examine various senses of 'nature' and 'natural' at work in his thought. In so doing, we will be able to survey the contents of and limits to Descartes' naturalism about the mental.

1 Descartes and pure intellect

The place of pure intellect in Descartes' philosophy can best be understood by contrast with a scholastic Aristotelian theory of cognition.[4] Aristotelians held that humans alone among mundane creatures possess a rational soul, which is the form of the human body. They attributed rational, sensory and vegetative powers to this soul. The sensory power comprised the traditional five external senses and several internal senses, including the faculty of imagination. An external sense such as vision receives sensible species (discussed below) from external objects. These species cause sense perception, and they are used to form images or phantasms in the imagination. According to Aristotelian theory, the senses and imagination require a bodily organ for their operation, but the intellectual faculty is an immaterial power that has no organ associated with it. Nonetheless, the intellect requires for its operation the presence of an image or phantasm in the imagination. As Thomas Aquinas (and many others) put it, quoting Aristotle, 'the soul understands nothing without a phantasm'.[5] There is no thought without an image.

The Aristotelian intellect was divided into active and passive. The passive intellect stores the 'intelligible species', or intellectual representations of the universal features of things. The active intellect creates the intelligible species, but only in conjunction with an image. The account of this act is complex and remarkable, for the intelligible species is not simply extracted from the images or sensible species in the imagination. The imagination, being corporeal, cannot affect the immaterial intellect. Hence, the species in the corporeal imagination cannot be transferred to the intellect. The active intellect must create a new entity, the intelligible species, in the passive intellect. But it can do so only in the presence of, or aided by, an image in the faculty of imagination. No image, no intelligible species.

Descartes believed there are materials available to the intellect which are unimagined in the Aristotelian scheme. That is, he asserted that he experienced purely intellectual representations of a kind the Aristotelians denied. The clearest contrast comes in the case of immaterial entities, namely God and the soul. Because there are no sensory images of immaterial beings, orthodox Aristotelians could not appeal to the normal process of forming intelligible species in explaining our ability to understand such beings (hence, the great interest in cognition through analogy). As Francisco Toledo (whose work Descartes knew) put it, an embodied intellect 'cannot naturally possess clear and distinct cognition of immaterial substance'.[6] By contrast, Descartes claimed that the idea of God was the 'most clear and distinct' of his ideas,[7] and he claimed to have a clear and distinct perception (intellectual cognition) of the immaterial mind. On my reading, neither of these acts of cognition has any relation to the senses. Descartes is not claiming to understand God by analogy with created things, rather he claims to find an idea of God in his mind only once he has withdrawn from the world of sense.[8] The idea of God is innate and immediate, and requires no image. Similarly, he is not claiming to know the immaterial nature of mind by scrutinising his own cognitive activity or by catching a direct glimpse of immaterial substance through introspection; rather, he is claiming to have an intellectual perception of mind as an immaterial substance.[9]

Descartes did not limit his claims about the deliverances of pure intellect to immaterial entities. He also claimed to grasp extension, the essence of body, by means of pure intellect. This claim is broached at the beginning of the Fifth Meditation, where Descartes' meditator says she distinctly 'imagines' continuous quantity or extension, and then goes on to realize that she can demonstrate things about various extended shapes, shapes she has never 'encountered through the senses'.[10] Early in the Sixth Meditation the meditator explicitly distinguishes the imagination and pure intellect, asserting that acts of pure understanding (or intellection) do not involve forming an image. Descartes illustrates this difference with the famous example of the triangle, chiliagon, and pentagon. He claims to understand a figure of a thousand sides even though he is unable to form a clear image of it, of the sort he easily forms in the case of a triangle. He goes on to assert that he is able to think of figures having only a few sides either through the intellect alone, or with the aid of an image:

> I can indeed understand the figure of a pentagon, just as I can the figure of a chiliagon, without the help of imagination; but I can also imagine the same figure, by applying my mind's eye to its five sides and the area they contain.

The felt difference between the two acts 'clearly shows the difference between imagination and pure understanding'.[11]

The deliverances of this pure intellect, or its 'clear and distinct' intellectual perceptions, undergird the central claims of the *Meditationes*. Depending on how one understands the *cogito* of the Second Meditation, that claim of existence may or may not be mediated by an intellectual grasp of a necessary connection between the presence of an attribute and existence of a thing. Supposing that it does involve such a grasping, then in this first instance of a 'clear and distinct perception' the meditator not only has an awareness of his own thought, but a further perception that 'it is not possible he should think without existing'.[12] In the Third Meditation it is 'manifest by the natural light' that the reality of the cause must equal or exceed that of the effect.[13] An additional major use of intellectual perception comes in the Sixth Meditation, where Descartes asserts simply that he 'observes' that 'nothing else belongs to my nature or essence, except that I am a thinking thing', from which he concludes that his essence 'consists in this one thing, that I am a thinking thing'.[14] Further, since he 'has a clear and distinct idea' of himself insofar as he is 'simply a thinking, non-extended thing', and he 'has a distinct idea of body, insofar as this is simply an extended, non-thinking thing', he concludes from these ideas, silently supplemented by the concept of a 'complete thing' or substance, that there is a real distinction between mind and body.[15] His clear and distinct understanding of body also leads to the conclusion that bodies possess those properties 'comprised within the subject-matter of pure mathematics', which have previously been identified as the properties of extension, including sizes, shapes, positions, and local motions.[16]

It is not my intention here to evaluate these arguments. I would observe that insofar as they rely on the intellectual perception of thinking substance as independent of extension, or the intellectual perception of pure extension, they rely crucially on appeals to the deliverances of pure intellect. In this context, the intellect is conceived as a truth-discerning power. It is of its nature to provide perceptions that are so clear that the will is compelled to assent to their content. And it is proper, Descartes tells us in the Fourth and Fifth Meditations, that we give our assent. If what Sellars called the 'logical space of reasons'[17] concerns justification of knowledge and hence validation of the truth of some beliefs, then Descartes' description of the intellect as a truth-discerning faculty places the operations of that faculty into the logical space of reasons. Of course, he who lives by the pure intellect will perish by the pure intellect, if he is unable to convince the rest of us that we have within us purely intellectual ideas of God, of mind as subsisting apart from matter, and of pure extension as the essence of matter. In that case, his arguments would fail because the presumed deliverances of the pure intellect are not received by others, not because he fallaciously inserted talk of mental faculties into talk of justification. As I shall elaborate more fully in section 5, it is only once one has given up on the power of pure intellect and related conceptions that one can treat descriptions of mental operations as irrelevant to justification within the logical space of reasons.

2 Descartes' naturalism about mind (and body)

Descartes proposed other departures from scholastic Aristotelian accounts of the cognitive faculties. His theory of the senses marked a radical break. Descartes' account of sense perception has been interpreted as promoting two modern trends. First, it has seemed to provide a transition from Aristotelian animism to modern naturalism about the human body. Second, it has seemed to initiate the exclusion of mind from nature. Although both of these attributions have some basis in Descartes' work, neither gets its point right. Let us see why.

In Descartes' time physiology was dominated by a synthesis of Galenic anatomy and physiology with Aristotelian natural philosophy.[18] Orthodox Aristotelians and Galenic physiologists both considered the nerves to be corporeal and to contain animal spirits, and both considered sensation to be a bodily state, a state of the sense organs and nerves. But they did not think of these bodily organs in purely mechanical terms. Rather, they attributed sensation to nerves and brain centres infused with the animate power of the sensory soul. Although Descartes held that sensation and imagination depend on bodily organs as their causes, he rendered the nerves as purely mechanical. He brought sensations and imaginings themselves into the immaterial mind, and thereby established a strict divide between mechanistic, bodily processes, and the resultant mentalistic sensations.

Descartes' mechanistic rethinking of the sensory process extended to the physics of external objects and their causal influence on the sense organs. The Aristotelians attributed colours to objects as basic properties or 'real qualities'. When we see a colour, it is activated by light and the 'form' of the colour is transmitted through the air as a sensible or intentional species, which is received in the eye and passes down the optic nerve into the brain. Intentional species do not render the eye coloured, but in affecting the sensory soul they provide the content to colour experience.[19] Descartes rejected what he said were 'all those little images flitting through the air, called intentional species'.[20] He accounted for the effect of distant objects on the sense organs through purely mechanical jostlings of particles against one another and against the matter composing the nerve fibres. He conceived the nerves themselves as thin fibres running inside hollow tubes, and action on the nerves as the jiggling of those fibres. For Descartes, then, the process of sense perception was fully mechanical up to the seat of mind–body interaction in the pineal gland.

It has been usual to view Descartes' altered account of sense perception as a 'naturalisation' of the causal process in the medium and nerves, which restricted the mental part of perception to a mind now isolated from (rather than informing) the body.[21] This interpretation is part of a general picture, promulgated by Burtt and others, according to which the heritage of the Scientific Revolution of the seventeenth century was a mathematisation of nature, so that the natural was equated with systems of particles varying only in size, shape, and motion (or, later, in mass, acceleration, and attractive or repulsive force).[22] The equation of matter with extension and the exclusion of mind from nature would, in contrast with Aristotelianism, be doubly novel. First, it banishes real qualities and substantial forms from body (as Descartes surely intended). But, second, it fully displaces soul or mind from the category of physics or natural philosophy (which, I will argue, Descartes did not intend). In the Aristotelian division of knowledge, the topics covered in *De anima* and the *Parva naturalia* were part of physics considered as the science of nature in general, and the human soul was therefore considered part of nature. Indeed, the section on the soul took up a significant portion of Aristotelian textbooks with the title 'physics' well into the eighteenth century.[23] If the second exclusionary thesis were right, Descartes would continue to discuss nervous physiology under physics (as had Aristotelians), but not mind–body interaction and the nature of mind itself.

The picture of the Scientific Revolution as leading to the equation of nature with a system of particles devoid of mind was current in the late nineteenth-century writings of Thomas Huxley and others. According to this story, the physical and the natural are coincident with the material. It is against this portrayal of the metaphysical foundations of modern physical science that Burtt directed his book (in which he repudiated the banishment of mind from nature).[24] I question whether this picture accurately represents any of the major advocates, agents, or interpreters of the new science (save Hobbes, who counts as an advocate). Descartes and others did of course attempt to mathematise matter, that is, they treated matter as capable of exhaustive description via geometry. What is in question is whether they took the natural world to be coextensive with the material world. I will argue that Descartes and several of his followers did not. To the contrary, they variously considered either some aspects of mind, or the human mind in general, to be part of nature.

In asking whether Descartes or others included the mind in nature, we need to specify what is meant by 'nature'. If we mean by nature the material world (full stop), then Descartes evidently did exclude mind from nature and that is the end of the story. However, I am posing the question with respect to the conceptions of nature extant in the seventeenth century. If we are to assess the claim that Descartes excluded mind from nature, we must avoid initially defining 'nature' in such a way that the claim immediately follows. Instead, we should be willing to let Descartes and his followers express their own conceptions of what falls under that term.

When Descartes composed his works a variety of senses of 'nature' and its cognates (Greek *physis*, Latin *natura*, and French *nature*) were extant,[25] and he employed many of them. He frequently used the term 'nature' to describe the essence of a thing or kind of thing, whether God, mind, matter, motion, or a triangle. Immaterial, material, and presumably non-existent objects (such as perfect triangles) all have natures in this usage. There is, however, no implication that what has a nature is natural (i.e. found in nature). God has a nature in this usage, but that does not make him part of the natural world. To answer our question about whether the mind was included in nature, we need to consider uses of that term as referring to the world as a whole and its contents.

In what Descartes calls its 'general aspect', nature means 'God himself, or the ordered system of created things established by God'.[26] This is God as an ordering, efficient cause, sometimes personified as intelligent, creative Nature, existing beyond the world as a whole but responsible for its order. This sense is found in the *Meditationes*, when Descartes is discussing what God has bestowed on his mind, and especially on the mind–body composite. Descartes invokes it in the Sixth Meditation with respect to the 'teachings of nature', which include our tendency to avoid pain and its cause. God bestows such 'teachings' on the human mind–body composite by adjusting causal relations between nervous states and mental consequence so as to promote the preservation of the body. This concept of Nature carries a teleological and providential connotation, upon which Descartes drew (in both the Fourth and Sixth Meditations).

In other instances the natural is contrasted with the supernatural, as in Descartes' talk of the 'light of nature', or 'natural light'. In Descartes' time the phrase 'light of nature' was well established, and carried an implied contrast with the 'light of grace'.[27] The latter phrase pertains to something an individual knows or believes not through natural cognition alone, but with divine aid. As 'natural', the natural light is simply contrasted with the supernatural or divine.

In both the providential and the non-supernatural senses of 'nature' the mind itself and the mind–body composite are part of nature. These usages have Descartes leaving the mind within nature as had the Aristotelians. But they do not make him the originator of modern naturalism about either mind or body, for the first usage implies divinely ordered teleology, and the second simply contrasts the natural with the supernatural, making natural everything apart from God (and angels).

Consider for a moment the now familiar sense of nature as the physical world as a whole, where physical implies material. This concept of nature and the natural is narrower than previous meanings, on two counts. First, the object of physics as a province of knowledge is restricted to the general properties of matter. Second, nature is restricted to the physical. It is only once a materialistic physics comes to be regarded as the universal science of nature that the physical (in the narrowed sense) exhausts the natural. These two developments were completed only in the nineteenth century (though the restricted sense of 'natural' has never achieved universality). Descartes played an important early role, by formulating a bold statement of the position that all phenomena of the 'visible world', whether terrestrial or celestial, could be understood as the product of purely material processes governed by a few laws and principles.[28] These 'laws of nature' retain the sense of Nature as God the ordering cause, but now the ordering is without teleological foresight (it merely preserves the quantity of motion).[29] Beyond an appeal to God to enforce its laws, Descartes' visible world is restricted to geometrically described matter. If the 'natural' were restricted to the 'physical' (in the sense of the object of physics), and if both referred only to the world of matter, then Descartes would have physicalised and naturalised the world, restricting teleological talk to minds and the mind–body complex, and banishing the mental from the physical and natural world in this narrowed sense.

Neither Descartes nor his followers unequivocally restricted the natural world to the physical world, and the physical world to the world of matter. But they sometimes wrote as if they did. Such talk coexists with expressed conceptions of physics and nature as including mental states, or indeed as including the human mind in general. Let us consider both ways of talking.

In several passages from the *Meditationes* and *Principia* Descartes treats the physical world and, coordinately, the natural world, as coextensive with the material world – that is, with a large soup of variously sized and shaped particles moving with various directions and speeds. In the letter to Clerselier in the French version of the *Meditationes*, Descartes says that 'mathematical extension' is 'the principle' of his physics.[30] And famously, in the postil to article 64 in Part II of the *Principia*, he says that 'I do not admit or desire any other principles in physics than in geometry or abstract mathematics, since all the phenomena of nature are explained thereby'. In the article itself he says that he considers only 'divisions, shapes and motions' in matter and that no other principles 'ought to be admitted, or even desired, in physics'.[31] Earlier, in letters of 1639 and

1640, he had said that all his physics is 'nothing but mechanics', and he suggested that physics might be 'reduced to the laws of mathematics'.[32]

These statements fit with, and are part of the basis for, the 'mathematisation of nature' interpretation of the Scientific Revolution and Descartes' part in it. They must be balanced against other statements in which nature includes mind, and physics studies aspects of mind.

In his description of *Le Monde* in Part Five of the *Discours*, Descartes describes the work as including not only the extant portions 'on light' and 'on man', but also a further portion on the rational soul and mind–body interaction.[33] If we recall that Descartes frequently called *Le Monde* his 'physics',[34] then these topics are included under that term. Somewhat more explicitly, in the Author's introductory letter to the *Principes*, Descartes includes study of the 'nature of man' under the rubric of physics. Now since we know that Descartes considered human beings to be a composite of body and mind, here he directly includes mind or soul, at least insofar as it is conjoined to body in human beings, within physics. In Part IV of the *Principia* he speaks of the unfinished fifth and sixth parts, the latter to have been on 'man'. He describes himself as 'borrowing' from that sixth part, in order to complete his treatment of 'material things' by accounting for sensory qualities. What he 'borrows' pertains not only to the material basis of sense perception in the properties of external bodies, the sense organs, and brain, but also to the relation between the human mind and its nervous system.[35] Presumably, this material would have been included in the discussion of the nature of 'man' under the rubric of physics. Finally, in the *Passions*, Descartes discusses brain physiology and its relation to mind. He does so, he tells us in a prefatory letter, not as 'an Orator, or even as a Moral Philosopher, but only as a Physicist (*en Physicien*)'.[36] Further, in Part One of that work he discusses the principles of soul–body interaction at length, and even touches on characteristics of the soul itself that do not depend on the body. In this context, he speaks in parallel of the 'functions of the body' and the 'functions of the soul'.[37] He is engaged in natural philosophical analysis of the mind–body complex, and of each member of that complex, as well as their interactive relations.

These passages provide strong evidence that Descartes included the mental effects of bodily states within the natural world, and under the purview of physics or natural philosophy. Although he banished the Aristotelian sensory soul from his physiology, he did not displace the mind from nature or from the discipline of physics. His physics includes the 'teachings of nature' instituted by God as an ordering efficient cause. Mind–body relations found in nature and falling under physics also include the rules or laws governing the production of sensations upon the occurrence of specific brain states. As we shall see in section 3, Descartes' physics includes a psychophysics.

Descartes also included the 'natural light' in the world of nature, as contrasted with the supernatural. Yet it is by no means clear that he considered study of the natural light to fall within the subject matter of physics. Descartes discussed the natural light and its use in his metaphysical *Meditationes* and in the metaphysical portion of the *Principia* (that is, Part I). In the 'Author's Letter' to the *Principes*, he described Part I as covering 'immaterial or Metaphysical things'.[38] It is here that he examines the truth-generating quality of clear and distinct perception and the natural light. In his extant works, discussion of mind falls within physics only in connection with mind–body interaction and the mental states produced thereby.

In failing to firmly classify study of the human intellect as a knowing power under the rubric of physics or natural philosophy, Descartes mirrors the equivocation of the Aristotelians. I have mentioned that the *De anima* topics were included under physics in the Aristotelian division of sciences. Although the Aristotelian soul was conceived as the form of the human body and not as a naturally distinct immaterial substance, it was nonetheless ascribed 'immaterial powers' of intellection. Study of these powers was sometimes ranged under physics, and sometimes under metaphysics.[39] As we shall see in section 4, Descartes' followers showed the same divide, some including only body-caused mental states in physics, others including the mind in general.[40]

3 Descartes, psychophysics, and sensory psychology

The fact that Descartes included at least aspects of the mind within physics leads to the realisation that despite his dualism – and in some cases because of it – he advanced a framework for an empirical science of the mind. As with his corporeal physics, Descartes used several kinds of argument to support his theories of mind and mind–body interaction. He called on purely intellectual perception to support his doctrine of the mind's indivisibility, non-extendedness and substantial distinctness from body. He appealed to observed behavioural capacities to argue that humans (who use language and are able to solve a variety of problems) have reason and intellect while animals do not.[41] And he appealed to the fact of sensory experience – or, as he put it cryptically to Elizabeth,[42] to things known 'very clearly by the senses' – to discover the existence of and rules for mind–body interaction, and hence the existence of the intellectual sub-faculties of sense and imagination (which depend on bodily interaction).

Relying on experience and hypothesis, Descartes produced a substantive body of empirically based natural-philosophical doctrine about mind, including an extended account of sense perception and a speculative physiology of the passions. Here we will focus on two areas within his natural philosophy of the senses: his posited psychophysical principles, and his hypothesis that unnoticed judgments underlie size and distance perception.

In Descartes' time the brain and nervous system were known to be the mediators of sensation.[43] As we have seen, Aristotelian and Galenic physiologists attributed a power of sentience to corporeal organs, nerves, animal spirits, and brain centres. Descartes sought to eliminate this power of sentience, or power of the sensory soul, in favour of purely mechanistic description of nerve action. His radical reconception of nerve and brain operation initiated the modern period of thought about the mind–body relation.

An immediate consequence of Descartes' radical mechanisation of nerve processes is that the mechanics of nerve function is the same for all senses. As we have seen, Descartes held that all sensory nerves are slender filaments running inside hollow tubes. In the brain the ends of these tubes and filaments form a hollow cavity surrounding the conarion, or pineal gland. External stimulation (mechanistically conceived) acts on the nerves at the organ and causes a tugging on the filament. Animal spirits, now conceived as particles of purely extended matter (devoid of sensory powers), flow outward from the pineal towards tubules opened by the tugging of the sensory nerve fibrils. In humans, the character of this outward flow determines the sensation felt by the mind in accordance with an 'institution of nature' governing (or constituting) mind–body interaction.[44] The modality of the sensation – whether the sensation is auditory, visual, olfactory, etc. – is not determined by features of the flow of spirits itself, but by the nerve group affected. Descartes recognized seven principal kinds of nerves, two that mediate internal sensations such as hunger or thirst, and five groups corresponding to the five external senses.[45] Putting his account of sensory modality together with his account of pineal physiology, it appears that stimulation of the nerve for one modality causes animal spirits to flow outward from one specific region of the pineal gland, stimulation of another sense causes flow from another area, and so on.[46] Variations of sensation within a sensory modality are then determined by specific features of nerve motion, which have a corresponding effect on pineal flow and thus on the mind (according to psychophysical laws discussed below). Thus, stimulation coming from the eye causes visual sensations because of an institution of nature, according to which pineal outflow that typically is caused by optical stimulation yields sensations of light and colour; the hue and intensity of colour sensations are determined by the specific character of the pineal flow, which in turn is regulated by the type and intensity of nerve jiggle produced by the stimulus. Sentience proper (conscious feeling, according to Descartes) arises only in the mind, as the result of purely mechanistic brain activity.

Descartes formulated his sensory physiology within a general mechanistic framework, but his specific hypotheses were guided by empirical evidence. He supported the framework through metaphysical arguments and appeal to the comparative simplicity and clarity of his explanations.[47] He used ordinary experience and medical evidence to establish specific claims, such as his claim that the modality of sensation depends not on the properties of the stimulus, but solely on which nerve is affected. Both kinds of argument are found in this passage from the *Dioptrique*:

> Regarding light and colour, the only qualities belonging properly to the sense of sight, we must suppose our soul to be of such a nature that what makes it have the sensation of light is the force of the movements taking place in the regions of the brain whence come the little fibres of the optic nerves, and what makes it have the sensation of colour is the manner of these movements – just as the movements in the nerves leading to the ears make the soul hear sounds, those in the nerves of the tongue make it taste flavours, and, in general, movements in the nerves anywhere in the body make the soul feel a titillation if they are moderate, and a pain when they are too violent – without there needing to be in all of this any resemblance whatsoever between the ideas the soul conceives and the movements that cause those ideas. You will easily believe this if you note that those who are wounded in the eye seem to see countless sparks and flashes before them, even though they shut their eyes or are in a very dark place; so that this sensation can be attributed only to the force of the blow, which sets the little fibres of the optic nerve in motion as a bright light would; and the same force, if it affected the ears, would make us hear a sound, and if it affected some other part of the body, would make us feel pain there.[48]

The point about sensory modality relies on ordinary experience and knowledge of the gross anatomy of the nervous system. The denial of any 'resemblance' between object and idea, and so the rejection of the sensible species of the scholastics, depends on Descartes' mechanistic framework. Sensible species were thought to explain the content of sense perception by establishing a 'real similitude' between a brain state and a property of the external object, as the result (in vision) of the transmission of a form without matter through the external medium and into the sense organs; this form, when expressed in the sensory soul, yields the phenomenal content of colour. Such forms or species are absent from Descartes' purely mechanistic account of sensory stimulation. As a result, sensations are viewed as the product of mind–body interaction.[49]

Descartes' replacement theory of sensory stimulation and phenomenal content ushered in three fundamental tenets of the modern theory of the senses: the doctrine of specific nerve energy, the resultant radical subjectivity of sensation, and the appeal to bare psychophysical rules or laws to express the relation between brain states and sensations. All three were central tenets of the natural scientific, experimental psychology of the nineteenth century.

Descartes' theory of the differentiation of sensory modalities is a direct analogue of the celebrated doctrine of specific nerve energy later advanced by Johannes Müller in the nineteenth century. Müller was a central figure in the early development of experimental psychology. The importance he assigned to the notion of specific nerve energies can be seen in his classification of the history of theories of vision into three epochs. In the first or dogmatic epoch, the nerves were ascribed a 'specific sensibility' for external stimuli, such as light or sound. On this view, 'sensations of light occur because an already available external light merely is sensed as such'.[50] The next epoch was that of physical research into optical stimulation by Newton and others, with little attention to physiological matters. The third epoch is physiological or theoretical. Müller proposed that the doctrine of specific nerve energies was the defining contribution of this third period. He expressed the doctrine as follows:

> That the energies of light, dark, colour are not immanent in external things, in the causes of excitation, but are immanent in the substance of the visual sense itself; that the visual substance cannot be affected without being active through its inborn energies of light, dark, colour; that light, shadow, and colours do not exist as something available external to the sense, which causes the sense simply to have a sensation of it; but that if the visual substance is moved from repose to feeling by any stimulus, of whatever type it may be, it itself produces in sensation the feeling with the energies of light, dark, colour.[51]

Whether the optic nerve is affected by pressure, vibration, or light, it yields a sensation of light.

Unlike Descartes, Müller was a vitalist who attributed sentience to the nerves themselves or their terminus in the brain. But his principle is analogous to Descartes' position in its recognition that the characteristics of sensation depend in a crucial way on the experiencing subject. If the same sensation can be produced by a variety of conditions, whether external or internal (including physical pressure on a nerve), then one cannot hold that the content of the sensation is 'absorbed' from the external stimulus, as the Aristotelian doctrine of sensible species would have it. Rather, the phenomenal content, such as an experience of colour, is provided by the subject, and varies depending on how the nervous system is stimulated.

Descartes was an early herald of the modern finding that a mechanistic conception of the stimulus and resultant neural activity entails the radical subjectivity of sensation. His work set the framework for the empirical investigation of a wide variety of relations between properties of the physical stimulus and sensations.

To see how this is so, we must distinguish the radical subjectivity thesis from related theses, including the claim that sensations lose all epistemic value in virtue of their subjectivity. The main point of the radical subjectivity thesis is that the phenomenal content of colour sensation is immanent to the experiencing subject. This point must be distinguished from one with which it is often associated: subjectivity as subject-dependent variability. Descartes attributed the latter kind of variability to both primary and secondary quality perceptions: the jaundiced person sees snow as yellow, and the distant person sees square towers as round.[52] Both cases provide cause for epistemic care in using the senses to determine object properties, but not cause for abandoning the senses. In any event, subject-dependent variability is not the source of Descartes' primary indictment of the epistemic value of colour sensation.

Descartes' primary indictment of colour sensations (and other secondary quality ideas) is that they are 'obscure and confused'. The obscurity or confusedness is not a property of colour sensations themselves, which, when taken as sensations, can be perceived clearly and distinctly.[53] Rather, colour sensations are 'obscure and confused' when considered as representations of object properties. Descartes denied that when we have a colour sensation we are made of aware of a 'real quality' in the object. When we (pre-metaphysically) say that we perceive colour in an object, it is as if we are saying that 'we perceive something in objects whose nature we do not know'.[54] No matter how much we scrutinise our colour sensations, we cannot tell whether they represent something in objects or not. But we can tell, from mature intellectual reflection, that bodies do not possess colour as a primitive property, since they possess only geometrical modes of extension (size, shape, motion, position). Consequently, colour sensations become, for Descartes, either obscure representations of features of the surfaces that reflect light, or mere arbitrary signs of those features. They are 'arbitrary' in that there is nothing intrinsic in the content of a colour sensation that would by itself tell you what sort of surface formation it represents.[55]

If we try to use our colour sensations alone to determine what colour is as a property of objects, we fail. But, as a result of metaphysical reflection, Descartes is sure that colour in objects is determined by the arrangement of particles on the surfaces of objects and the consequent effect on the spin of light particles. So, upon such reflection, we can know what sort of object-property colour is. We can, as he says, know the 'nature' of colour as a bodily property: 'colours are nothing else, in the bodies we call coloured, than the diverse ways in which these bodies receive light and reflect it against our eyes'.[56] We can also know the 'nature' of coloured light: it is spin on particles.[57] Moreover, various colour sensations tell us that now one, now another surface formation is present (or now one, now another spin). In accordance with the institution of nature, there is a regular relation between surface formations and colour sensations. This relation is mediated by the regular effect of surfaces on light, the effect of light on the nervous system, and the effect of brain activity on the mind. For Descartes, the phenomenal content of colour sensation is subject-dependent, but the conditions in which colour sensations are produced are objective. Consequently, one can use colour sensations to tell objects apart,[58] and to gain other objective knowledge about mind-independent objects (such as he claimed to discover about the rainbow).[59]

The relation between external surface properties and colour sensation, or between physical light and colour sensation, were later called psychophysical regularities. They are regular or lawful relations between physical attributes of a stimulus and the occurrence of a sensation of a particular type, or with a given magnitude (as in the loudness of a pitch or the brightness of light). Descartes proposed several psychophysical regularities. In addition to those for colour, he noted that the quantity of light sensed varies with the intensity of the motion produced in the optic nerve. He gave a psychophysical explanation for acuity based on the grain of retinal receptors, and for perceived position (direction in relation to the body) based on retinal location and a sense of head position.[60] His psychophysical explanation of distance perception is especially remarkable. Descartes argued that the neural processes that control the accommodation of the lens of the eye directly produce a perception of distance, without the intervention of other psychological processes.[61]

Descartes' theory of the subjectivity of sensation denies that sensations directly reveal the fundamental properties (or the nature) of objects. At the same time, his theory and its descendants provided a framework for the investigation of regular relations between the physical properties of objects, described in mechanistic terms, and the quality or intensity of sensations. Psychophysical investigations of this sort were carried out to a limited extent in the eighteenth century. In the nineteenth century psychophysics became a foundation of the new experimental psychology. The study of colour was a prime area of research. Through the efforts of Hermann Grassmann, Hermann Helmholtz, and J.C. Maxwell, precise equations relating the physical properties of light to perceived colour (or sameness of perceived colour) were developed. Such investigations ultimately provided the objective scientific basis for colour engineering, including colour film and colour television.[62] Descartes' principle that regularities exist between the properties of objects described in the language of modern physics and the phenomenal qualities of sensations was a common assumption underlying these developments, whether his role in formulating it was recognized or not.

Descartes did not account for all aspects of visual experience through direct psychophysical mechanisms or the institution of nature. He hypothesised that in some instances of size and distance perception, psychological operations are at work. More particularly, he hypothesised that the perception of size and distance sometimes relies on (unnoticed) judgments, which operate on an (hypothesised) sensory representation corresponding to the bidimensional retinal image. Descartes observed that the perceived size of objects does not vary directly with the size of the image they cast on the retina, but that (at least at near to moderate distances) we perceive their size by taking their distance from us into account. He argued as follows

> This is sufficiently obvious from the fact that even though the images are, for example, one hundred times larger when the objects are very close to us than when they are ten times further away, they do not for all that make us see the objects one hundred times larger, but nearly the same size, at least if the objects' distance does not deceive us.[63]

Put in other terms, one's own hand does not appear four times larger when held at one foot than when at two feet from one's nose.[64] Descartes suggested that information about visual angle as contained in the retinal image is combined with perceived or judged distance through an unnoticed judgment. The product of such a judgment is psychologically mediate, but, in accordance with Descartes' description, it is phenomenally immediate. This is in contrast with the psychologically immediate representation of the retinal image, which Descartes maintains is not phenomenally immediate (otherwise our experience of size would vary inversely with distance, and the hand would appear four times larger). The sensory representation of the bidimensional image is a theoretical posit for Descartes.

Descartes' explanation of size perception by appeal to unnoticed judgments was less novel than his psychophysical programme, because it drew upon a long tradition of the analysis of posited judgmental processes in the perception of size and distance.[65] Nonetheless, Descartes' contribution here is of significance. The quotation about a thing appearing to have an equal size at different distances provided a prominent description of what was later called 'size constancy'. Some modern authors writing on mathematical optics defined 'perceived magnitude' simply in terms of visual angle, apparently denying Descartes' phenomenological observation that objects do not increase or decrease in perceived size in direct proportion to visual angle. Other authors, who were interested in analyzing the processes underlying phenomenal experience, could find in the writings of Descartes and his followers a clear description of a fundamental problem of size perception.[66] Unnoticed judgments or other psychological operations have been a regular staple, and an area of theoretical competition, among writers on the psychology of vision from Descartes' time to our own.

With his substance dualism in place, and with no purely intellectual understanding available of mind–body interaction (as he confessed to Elizabeth), Descartes realised that questions of mind–body interaction could only be addressed empirically. He approached mind–body interaction by noting regular correspondences among stimuli, hypothesised nerve processes, and sensations. As in the mechanistic parts of his physics, Descartes was not shy about positing unobserved entities in his sensory psychology. Such entities include not only the hypothetical hydraulics of the nerves and pineal gland, but also the characteristics he attributed to the sensory states that arise at the pineal, such as the bidimensional image in size perception. Throughout his physics, including its psychological portions, Descartes used metaphysics to provide a general framework, within which he proposed hypothetical processes or mechanisms to account for the phenomena. He initiated a Cartesian natural philosophy of the physiology and psychology of the senses, which was carried on by subsequent Cartesians.

4 Mind and some Cartesians

Although the notion of counting an immaterial substance as a natural thing whose powers may be studied empirically is foreign to philosophy and psychology today, it would not have seemed odd in Descartes' time. When Descartes wrote, an immaterial substance could count as part of nature, and study of at least some of its functions could belong to physics or natural philosophy. At the same time, there was divided opinion, among both Aristotelians and Cartesians, about whether the natural light of the intellect – which was 'natural' simply by contrast with the supernatural – was a proper object of study in physics. Descartes' followers adopted a spectrum of positions on which aspects of mind fall within physics. From among the many Cartesians, we will sample three representatives: Le Grand, Rohault, and Regis.

Antoine Le Grand was the author of an early comprehensive rendering of Descartes' philosophy. He divided philosophy into the traditional four areas of logic, metaphysics, natural philosophy, and ethics. Aspects of mind are considered under all four. Ethics considers the nature of virtue and the rules of right conduct, and serves as an 'art' for directing the will of man. Logic is an 'art' intended to 'assist the Understanding in the discovery of Truth'. It includes discussion of all of the faculties that can be involved in forming judgments, including understanding, imagination, sense, and will. Its aim is to aid human beings in perceiving, judging, reasoning, and ordering their knowledge rightly.[67] Metaphysics includes 'pneumatics' or the study of immaterial beings, under which falls 'psychology', or study of the 'constitution of the Mind of Man, its Faculties and Passions'. This nested classification scheme would technically place psychology under metaphysics, together with the chapters on God and the angels. But no chapter on human psychology occurs in the parts of Le Grand's book devoted to metaphysics; rather, he deferred discussion of the human mind to Part 9, which falls within natural philosophy.[68]

Le Grand restricted the scope of 'Physiology', or natural philosophy, to things that 'belong to Body, its Forms or Affections'.[69] Nominally, he gave 'physics' the same subject matter as it had in Aristotelian textbooks. However, to see the precise compass Le Grand assigned to physics we must interpret his notions of body and form. He rehearsed the orthodox Cartesian position that the essence of body is extension. He assigned to matter the 'intelligible forms' magnitude, figure, situation, motion and rest, and allowed only two forms in nature that are not modes of extension. The first is God as the cause of motion in the world in general. As he put it, God is the 'soul of the World' in that he 'holds together the dispersed Parts of the World, animating, governing and cherishing them' – an opinion he believed was not contrary to faith, 'Provided always that GOD be understood not to be the Informing Soul of the World, that is, a Constitutive part of it; but an Assistant form only, that is, the Ruler and Governour of Nature'.[70] God is an 'assistant' or assisting form. Le Grand denied substantial forms, except the human soul.[71] His formal definition of the essence of man is 'a thing compounded of a Finite Mind, and a rightly disposed or framed Body'.[72] In this sense, the soul is a principle of activity of the human body, or the substantial form of the human being.[73]

Corresponding to his definition, Le Grande divided the science of 'Man' into two parts, pertaining to the human body and mind. The topics covered in the section on body include anatomy, reproductive physiology, respiration, and metabolism. The section on body also includes the interaction of the nervous system with the soul, and the contribution of the soul to the visual perception of position, distance, size, and shape. The part on mind proper in Le Grand's physics examines the substantial nature of mind, the remaining faculties, including understanding, imagination, will, and memory, and the theory of mind–body union. Interestingly, he defined the latter simply in terms of regularities of interaction: 'The Union of Soul and Body consists in an Actual dependency of all the Cogitations of the Soul, upon certain motions of the Body; and of some certain motions of the Body, upon some Cogitations of the Soul.'[74] The union consists entirely in the dependency, or conditional correlation, of mental state on bodily state, and vice versa.

Jacques Rohault, author of the most widely distributed textbook of Cartesian physics in the century after Descartes, followed the extant *Principia* in mainly treating topics pertaining to the material world. He nowhere gave a specific definition of the term 'natural', but he did write in a way that preserved the Aristotelian breadth of the term. In the preface he indicated that some topics, which were usually treated at the end of natural philosophy in connection with Aristotle's *De anima*, were treated in Part I of his work, for 'this teaches us to know ourselves' and allows us to avoid error.[75] In his definition of physics, he said that, strictly speaking, 'Physicks' simply means 'natural', but that here it signifies 'the Knowledge of natural Things, that is, that Knowledge which leads us to the Reasons and Causes of every Effect which Nature produces'.[76] Among the 'Notions that precede the Study of Natural Philosophy' he included knowledge 'that there are Things really existing in the World', and among such 'things' is 'That which Thinks', that is, soul or spirit, whose existence is known to us (via the *cogito*) before we know that body exists. Moreover, in discussing the axioms of natural philosophy, he included effects within his 'own self', that is, in his mind, among those that are to be explained by causes internal or external to ourselves.[77] In his discussion of the perception of the qualities of bodies he covered both bodily and mental aspects. He devoted the most attention to vision, including the perception of colour, size, and distance, the production of an 'immaterial Image' in the soul through brain activity, and the 'judgments' based on that image which result in size and distance perception.[78]

Pierre Régis' popular 'system' of Descartes' philosophy covered logic, metaphysics, physics, and morals. He assigned treatment of the existence and nature of mind and body, and of the mind–body union, to metaphysics; unlike Le Grand, he restricted discussion of the soul as an immaterial being to that discipline.[79] But he followed the usual pattern of including the mind–body union, and the resultant production of sensations in the mind, within physics. Of the seven volumes in the Lyon edition of the *Système de philosophie*, five were devoted to physics, with more than a full volume devoted to the cognitive faculties and passions. Regis described in detail the hypothetical brain processes, or '*causes physiques*', associated with sense, imagination, judgment, reason, and memory. As was usual, the sense of vision received the greatest attention, including colour perception, the formation of a 'spiritual image' (or imagistic experience), binocular single vision, size and distance perception, and the moon illusion.[80] He held that all sensation results from brain activity, and that the causal relation is mediated by God. Turning aside the view that a body can act on mind just as it acts on other bodies, Regis argued that:

> the brain acts on the soul in a special way, which consists in God having resolved to produce sensations in the soul in accordance with the laws of the union every time there are certain movements in the brain. From which it follows that, in this respect, these movements can and should be considered the true physical and natural causes of the sensations.[81]

God acts constantly to uphold the laws of mind–body interaction, which apparently are to be regarded as natural or physical laws. The union itself he termed a 'physical' union of reciprocal dependence.[82]

Having sampled some Cartesian positions about the mind's place in nature, let us return to the question of whether Descartes and his followers 'naturalised' the physiology of the senses. Since Descartes and our Cartesians kept the mind–body interaction within nature, it is misleading to say that in deanimating sensory physiology they naturalised it. The Aristotelians had, in any case, considered their substantial forms and real qualities to be a part of nature. From Descartes' point of view, the comparative virtue of his position was not that it naturalised bodily processes, but that it provided true explanations of them. He sought to explain bodily processes without appeal to substantial forms or to mind-like entities, which he regarded as unparsimonious and ad hoc. He mechanicised sensory physiology, but for him mechanisation was not naturalisation. It is only retrospectively, in the eyes of later admirers who equated nature with the material or the mechanical, that Descartes could be seen as naturalising body in contrast to mind. From a Cartesian perspective, adopting a mechanical philosophy of body does not have the effect of excluding mind from nature. On the contrary, mind–body interaction is part of the natural world, subject to natural laws, and within the subject matter of physics.

5 Mind, psychology, and epistemology

Descartes the natural philosopher included the regularities of mind–body interaction in the natural world. Descartes the metaphysician and seeker of cognitive validity appealed to the deliverances of the faculty of pure intellect for his firm foundations. He classified the operation of that intellect as natural, at least by contrast with the supernatural. In the mid-twentieth century this appeal to mental operations looked like an instance of the naturalistic fallacy of psychologism.[83] Consequently, many recent philosophers have deemed it best to ignore or minimise the role of faculty psychology in early modern philosophy.

We are now in a position to see how the charge of psychologism misses the point. The notion of a naturalistic fallacy in epistemology presupposes a substantive philosophical position, to the effect that the natural operations of the human mind do not set the standards of true cognition and right reasoning. It involves the supposition that the natural operations of the mind do not essentially yield justified or warranted beliefs, and so cannot themselves be used as epistemic standards. This supposition denies a philosophical position held by the Aristotelians and Descartes. Both considered mind to be part of nature, and yet both considered that its operations 'naturally' – as opposed to supernaturally – yield true cognition and right reasoning. As the Aristotelians put it, the mind naturally tends toward right reasoning. Logic is not intended to teach the mind to reason correctly – that cannot be done – but to help it avoid leaving the path. As Descartes put it, the natural light of the intellect is the ultimate standard of true cognition in cases such as the *cogito*, 'because there cannot be another faculty which is equally trustworthy as this light and capable of showing me that such things are not true'.[84]

On this view, the operations of the intellect are inherently normative, they inherently provide the epistemic standard for true cognition.[85] To say that the intellect is inherently normative is to say more than that normative standards, or standards of right and wrong use, apply to it. Normative standards apply to any mental capacity that is used to form beliefs, including epistemically neutral capacities, such as the ability to form a mental habit. Epistemic norms can be used to evaluate various practices of habit formation, with the result that some practices are deemed epistemically superior to others. But that does not make habit formation inherently normative. With an inherently normative faculty such as the Cartesian intellect, its best use sets the norm for epistemically evaluating all other faculties, including its own less than optimal uses (as when, in Cartesian terms, we assent to something that we do not perceive clearly and distinctly). As Descartes saw it, the right use of the intellect cannot itself be taught or learned, but it can be discovered to lie within one's power. One must then simply allow the intellect and will to operate undisturbed in order to gain true cognition.

Descartes' attitude toward the mind's intellectual faculty was epistemic, not psychologistic. He regarded the intellect as a knowing power whose operations set the only standard for truth available to human beings. Later philosophers rejected this conception of the power of the intellect. Kant in particular rejected this view, and he sought to exclude mind as a knowing power from the natural domain. He distinguished between empirical psychology, which he placed under 'physiology' or the study of nature in general, and transcendental philosophy, which examined the conditions for knowing. He thereby rendered the empirically knowable mind as merely natural.[86] Its natural operations could then be set in contrast with, and held subject to, independent normative standards.

For Descartes and our Cartesians natural and normative were not contrastive. These authors used disciplinary distinctions to set the study of mind as a knowing power apart from the natural philosophy or 'physics' of mind. Under the aegis of natural philosophy they studied the material circumstances of reasoning, the operation of mind in conjunction with the mind–body complex, and the aspects of the mind–body union that lead to preservation of the body. They reserved study of the natural light and its operation to metaphysics and logic. In metaphysics one might discover and describe the truth-discerning power of the natural light. In logic one would offer guides for its right use. But logic offers no independent norms for the natural light; its results are derived through the use of the intellect itself, in accordance with the standard of clear and distinct perception.

It is a sign of the philosophical distance separating us from Descartes' conception of the intellectual power of mind that some recent philosophers could describe him as a psychologistic naturaliser. This description mistakes our primary disagreement with Descartes on matters epistemic, which is a disagreement over the power of the intellect. At the same time, the special power Descartes assigned to intellect should not blind us to another side of his philosophy, his naturalism about mind–body interaction and body-caused mental states. Here is a Cartesian naturalism that deserves our continuing attention. Why can there not be naturalism about the mental? Why should genuinely mental states not be considered part of nature, and study of the psychophysical laws governing their production part of natural science? These questions, too, are part of Descartes' philosophical legacy.[87]

Notes

1 E.A. Burtt, *The Metaphysical Foundations of Modern Science* (London, 1932), 312, 319; Wilfrid Sellars, 'Philosophy and the scientific image of man', in his *Science, Perception, and Reality* (London, 1963), 1–40: 18–25; Margaret D. Wilson, *Descartes* (London, 1978), 99. See also R.G. Collingwood, *The Idea of Nature* (Oxford, 1945), 103.

2 I use the term 'psychophysics' here with the general meaning it was given in the nineteenth century: study of the relations between physical states and mental states. The classical nineteenth-century work is Gustav Fechner, *Elemente der Psychophysik*, 2 vols. (Leipzig, 1860).

3 John Dewey, 'Psychologism', in the Dictionary of Philosophy and Psychology, ed. James Mark Baldwin, 3 vols. (New York, 1901–5), ii. 382.

4 In a letter to Mersenne dated 30 September 1640, Descartes remembered several scholastic Aristotelian authors from twenty years earlier: Antonio Rubio, Francisco Toledo, the Coimbran commentators, and Eustace of St. Paul (AT iii. 185). In this and the following sections I describe doctrines concerning the senses and intellect, or the cognitive faculties more generally, that were commonly held by these authors (and many others). Nonetheless, it must be kept in mind that those purporting to interpret Aristotle developed a wide range of positions, including ones in which all human intellection is performed through the agency of a supermundane power. Consequently, my use of the phrase 'the scholastic Aristotelians' in this chapter refers only to the authors explicitly named in this note or cited further on. For a summary of the positions of these and other authors on the cognitive faculties, noting commonalities and recording some differences, see G. Hatfield, 'Cognitive Faculties', in M. Ayers and D. Garber, eds., *The Cambridge History of Seventeenth Century Philosophy* (Cambridge, 1998), 953–1002: 954–61.

5 Aquinas, *Summa Theologica*, trans. Fathers of the English Dominican Province, 21 vols., hereafter 'ST' (London, 1911–25), pt. I, qu. 84, art. 7, *sed contra*, quoting Aristotle's *De anima*, bk. 3, ch. 7. The Latin is: '*nihil sine phantasmate intelligit anima*': *Summa theologiae*, 61 vols. (Cambridge, 1964–81). The Latin *phantasma* is often translated as 'image', and in these discussions has the connotation of a sensory image or image in the imagination (or 'phantasy'). Other Latin words that sometimes can mean image include *idea*, *forma*, *simulacrum* and *species*, but to preserve their technical philosophical meanings they are usually translated as 'idea', 'form', 'simulacrum', and 'species'. When Latin *imago* occurs in these discussions it is usually close to its root meaning of an imitative copy such as a statue or painting. For other expressions of the doctrine that there is no intellection without an image, see Francisco Toledo, *Commentaria una cum quaestionibus in tres libros Aristotelis De anima*, hereafter 'CDA' (Köln, 1594), proem, qu. 2, ad 5 (fol. 4v); Coimbra College, *Commentarii in tres libros De anima*, hereafter 'CDA' (Köln, n.d., ca. 1600), bk. 3, ch. 5, qu. 3, art. 2 (pp. 383–4), bk. 3, ch. 8, qu. 8, art. 2 (pp. 453–5); Antonio Rubio, *Commentarii in libros Aristotelis Stagyritae philosophorum principis, De anima*, hereafter 'CDA' (Lyon, 1620), 'Tractatus de intellectu agente', qu. 2–3 (pp. 637–46), 'Tractatus de natura, actu et obiecto intellectus possibilis', qu. 7 (pp. 692–3); Eustace of St. Paul, *Summa philosophiae quadripartita*, 4 parts (Köln, 1638), pt. III, 'Physica'

(hereafter, 'SP-P'), pt. 3, treat. 4, disp. 2, qu. 7, 10 (pp. 290–3, 298); and Francisco Suárez, *De anima*, bk. 4, ch. 7, art. 3, in his *Opera omnia*, ed. M. Andre, 26 vols. (Paris, 1856–78), iii. 739.

6 Toledo, CDA, bk. 3, ch. 7, qu. 23, concl. 3: '*Intellectus in corpore non potest habere naturaliter claram & distinctam cognitionem substantiae immaterialis*' (fol. 168ra); also, concl. 4: '*Substantiae immateriales a nobis confusem in hoc statu cognoscuntur*' (fol. 168rb). Others said similar things: Aquinas, ST, I. 87.3; I. 88; Coimbra College, CDA, bk. 3, ch. 5, qu. 5, art. 2 (pp. 402–3); bk. 3, ch. 8, qu. 7, art. 2 (p. 449); qu. 8, art. 2 (pp. 453–5); and Rubio, CDA, bk. 3, chs. 4–5, 'Tractatus de intellectu possibili', qus. 5–6 (pp. 680–9). See also Eustace of St. Paul, SP-P, pt. 3, treat. 4, disp. 2, qu. 4–5, 7 (pp. 287–9, 290–3).

7 *Meditationes de prima philosophia*, III, AT vii. 46.

8 This reading is developed and defended in G. Hatfield, 'The senses and the fleshless eye: The *Meditations* as cognitive exercises', in Amélie Rorty, ed., *Articles on Descartes' Meditations* (Berkeley, 1986), 45–79, and 'Reason, Nature, and God in Descartes', in Stephen Voss, ed., *Essays on the Philosophy and Science of René Descartes* (New York, 1993), 259–87.

9 Care is needed here. Descartes surely claims to know the existence of mind, its contents, and activities by introspection, and he would claim to be acquainted with the ideas of God and of human mental substance in the same way. But the ideas of God and mental substance are themselves purely intellectual graspings of immaterial substances. In the case of mind, this grasping cannot be based solely on an awareness of mental acts; these serve as evidence of the existence of mental substance, but not as essential content in the apprehension of that substance itself, as when Descartes claims to have a 'clear and distinct idea of myself, insofar as I am simply a thinking, non-extended thing' (AT vii. 78). In the *Principia philosophiae*, I, art. 53 (AT viiiA. 25) he teaches that the existence of a substance can be cognized via any of its modes, but its nature or essence is known through its chief attribute, whether thought or extension. And he asserts that mind and body 'are most clearly and distinctly understood' when conceived as 'thinking substance itself and extended substance itself', *Principia*, I, art. 63, AT viiiA. 31. We can think of thinking substance without thinking of any particular mode of thought, whereas, of course, he maintained that we cannot understand a mode of thought without attributing it to a thinking substance.

10 AT vii. 63–4.

11 AT vii. 72–3.

12 *Meditationes*, III, AT vii. 35; Second Replies, AT vii. 140.

13 AT vii. 40, 47; it is also 'manifest by the natural light' that the distinction between preservation and creation is a conceptual one (AT vii. 49). The 'natural light' is Descartes' term for pure intellect in its bare capacity of perceiving truths. For some previous uses of this term, and possible relations to Descartes, see John Morris, 'Descartes' Natural Light', *Journal of the History of Philosophy* vol. 11 (1973), 169–87.

14 AT vii. 78. It is clear from context that he 'clearly and distinctly understands' what he 'observes' about mind.

15 AT vii. 78. The additional notions about substance and complete being are explicitly supplied at the ends of the First and Second Replies, AT vii. 121, 161.

16 AT vii. 80; Meditation V, AT vii. 63. Descartes says that bodies 'at least', or 'in any event' (*saltem*) possess these mathematically described attributes. He goes on to explain that he should not attribute other candidate properties to bodies, such as a property resembling his sensation of colour, since sensations are given him primarily for the preservation of body; he restricts to intellect alone decisions about what properly belongs to external bodies (AT vii. 82). As he reports in the *Principia*, I, art. 70, he can 'understand no similitude whatso-

ever' between colour sensations and their causes in external objects (AT viiiA. 34). In accordance with his proviso that the intellect should decide such matters, Descartes appears to rest his case for excluding colour as a real quality from body on a bare intellectual inspection of extension.

17 Wilfrid Sellars, 'Empiricism and the philosophy of mind', in his *Science, Perception, and Reality*, 127–96: 169.

18 On Renaissance 'neotraditional' physiology, see T.S. Hall, *History of General Physiology*, 2 vols. (Chicago, 1969), i. 188–205. On the scholastic Aristotelian theory of the senses, see Alison Simmons, 'Explaining sense perception: A scholastic challenge', *Philosophical Studies* vol. 73 (1994), 257–75. On Galen's pneumatic theory of the nerves, see Rudoph Siegel, *Galen on Sense Perception* (Basel, 1970), 46–7. On Descartes' physiology, see G. Hatfield, 'Descartes' physiology and psychology', in John Cottingham, ed., *Cambridge Companion to Descartes*, 335–70.

19 Intentional species are entities posited by the scholastics in their attempt to interpret Aristotle's doctrine of 'forms without matter' in sense perception. In scholastic Aristotelian theory they are not immaterial entities, devoid of material conditions; rather, they are related to their material conditions in a special way, such that the intentional species of red does not render the air or the eye red when they provide it with materiality. Intentional species are described as having 'diminished' being in the medium and organs. On the theoretical pressures that led scholastics to posit intentional species, see Simmons, 'Explaining sense perception.'

20 *Dioptrique*, AT vi. 85. Descartes' account of intentional species as small flitting images is a caricature, on which see Hatfield, 'Cognitive faculties', 958.

21 On Descartes as the herald of a new, materialistic interpretation of nature in relation to biology, see Hall, *History of General Physiology*, i. 250–64, and A.R. Hall, *The Revolution in Science, 1500–1750* (London, 1983), 167.

22 Burtt, *Metaphysical Foundations*, ch. 1. See also Richard Westfall, *The Construction of Modern Science* (New York, 1971), 3–33; Daniel Garber, 'Descartes' Physics', in Cottingham, ed., *The Cambridge Companion to Descartes*, 286–334. Westfall was careful to say that Descartes excluded mind from 'material nature', but he nonetheless equated Descartes' 'physical world' with the world of matter.

23 On the development of the concept of physics in general, see G. Hatfield, 'Was the Scientific Revolution really a revolution in science?,' in Jamil Ragep and Sally Ragep, eds., *Tradition, Transmission, Transformation* (Leiden, 1996), 489–525. On the development of the concept of psychology in relation to physics broadly conceived, see G. Hatfield, 'Remaking the science of mind: Psychology as a natural science', in Chrisopher Fox, Roy Porter, and Robert Wokler, eds., *Inventing Human Science* (Berkeley, 1995), 184–231.

24 Burtt, op. cit., ch. 8. T.H. Huxley, 'On Descartes' Discourse Touching the Method of Using One's Reason Rightly and of Seeking Scientific Truth', in his *Method and Results: Essays* (New York, 1896), 166–98: 189–94. Huxley saw the march of science as leading to the materialistic conclusion that if mind is to be understood, it will have to be understood in physical (spatio-temporally localisable) terms. But Huxley denied he was a materialist; he was prepared to follow materialism methodologically and in framing theories, but on epistemological grounds he rejected it as a metaphysics.

25 For a useful catalogue of senses of 'nature' and its cognates, see Arthur O. Lovejoy and George Boas, *Primitivism and Related Ideas in Antiquity* (Baltimore, 1935), 447–56.

26 Meditation VI, AT vii. 80.

27 Second Replies, AT vii. 148; Descartes to 'Hyperaspistes', AT iii. 426. See also Morris, 'Descartes' Natural Light'.

28 *Principia*, III, art. 1, AT viiiA. 80.
29 *Principia*, II, arts. 36–42, AT viiiA. 61–6.
30 *Meditationes metaphysiques*, AT ixA. 212.
31 AT viiiA. 78–9. It should be noted that in *Principia*, IV, art. 187, as Descartes turns to topics from the unwritten Part. VI, he qualifies his use of 'nature' up to that point in the work by making explicit that it has been restricted to those phenomena with corporeal, nonmental causes: 'in short, there is nothing in all of nature – or nothing that must be referred to purely corporeal causes, i.e., to causes devoid of mind and thought . . .' (AT viiiA. 315). This is consistent with his including corporeal causes of sensation within nature. But it also would be consistent with counting the sensations themselves among the 'natural phenomena', although Descartes did not include sensations among the phenomena of the 'visible world' in the *Principia* and used the term 'phenomena' to refer to the appearances of external objects, not to the sensations in virtue of which they appear (III, art. 1; IV, art. 199). More generally, the qualification in art. 187 is consistent with Descartes' including mental causes of bodily action in nature, while using the qualification itself to exclude such causes from discussion in that work.
32 Descartes to Debeaune, 30 April 1630, AT ii. 542; to Mersenne, 11 March 1640, AT iii. 39.
33 *Discours de la méthode*, AT vi. 42, 59.
34 Descartes to Mersenne, 25 November 1630, AT i. 179; to Mersenne, 27 February 1637, AT i. 348; see also to Mersenne, November or December 1632, AT i. 263.
35 *Principia*, IV, arts. 196–7.
36 *Passions de l'âme*, author's second letter, AT xi. 326. The French *physicien* is usually (and properly) rendered as 'physicist' (or, sometimes, 'natural philosopher') in this context, as the name for a person engaged in *physique* or physics. Still, given that Elizabeth had earlier referred to Descartes as the 'doctor' (*medicin*) of her soul (AT iii. 662), it is worth noting that Descartes may well have here been (flirtatiously?) playing on the fact that in seventeenth-century French the term *physicien*, as cognate with 'physician', could also mean *medicin*: *Grand Larousse de langue française*, 7 vols. (Paris, 1971–8), v. 4262; Pierre Richelet, *Dictionnaire françois*, 2 vols. (Geneva, 1679–80), ii. 157.
37 *Passions*, I, art. 17, AT xi. 342.
38 AT ixB. 10.
39 Toledo, CDA, proem, qu. 2 (fol. 4), Coimbra College, CDA, proem, qu. 1, art. 2 (pp. 7–8), and Rubio, CDA, proem, qu. 1 (pp. 10–11) subsumed the soul in all its operations, including immaterial ones, under physics, but they agreed that discussion of the rational soul when separated from the body belongs to metaphysics. They variously discussed the positions of unnamed 'recent' commentators as excluding the rational soul from physics on grounds such as that the intellect is incorruptible and so does not belong in physics, which treats of generation and corruption.
40 René le Bossu, *Parallele des principes de la physique d'Aristote, & de celle de René des Cartes* (Paris, 1674), reflects uncertainty about which aspects of mind Descartes included in his physics, but affirms that he did include at least some aspects: '*Ainsi l'homme même, & son ame, au moins en qualité d'ame sensitive, sera l'objet de la Physique de M. des Cartes, aussi bien que tout ce qu'il y a de matériel & d'étendu dans le monde qu'il nomme Corps*' (46).
41 *Discours*, AT vi. 58–9.
42 Descartes to Elizabeth, 28 June 1643, AT iii. 692.
43 Although Aristotle's and the Stoics' arguments in favour of the heart as the seat of human cognition were still mentioned (and their position was adopted by

Hobbes for a time), most investigators (including scholastic Aristotelians) followed Galen in making the brain the primary seat of cognition. On the ancient dispute, see Teun Tieleman, *Galen and Chrysippus on the Soul* (Leiden, 1996), 39–44. Thomas Hobbes, *Leviathan*, ed. R. Tuck (Cambridge, 1991), 13 (I, ch. 1), described the nerves as leading to the brain and heart in sensation. Some Aristotelians who favoured Galen over Aristotle on the seat of the common sense in the brain were Toledo, CDA, bk. 3, chap. 2, qu. 5 (fol. 120v–122r); Coimbra College, CDA, bk. 3, chap. 2, qu. 2, art. 2 (pp. 337–9); Rubio, CDA, bk. 3, chap. 3, qu. 7 (p. 614); and Eustace of St. Paul, SP-P, III.1, disp. 1, qu. 2 (p. 78). Descartes rehearsed several standard arguments for the crucial role of the brain in thought and sensations, including the radical effect on sensation of diseases of the brain, and of nerve lesions between the brain and an external limb, *Principia*, IV, art. 96. He also developed a new argument to show that in cases in which a limb has been removed by amputation, stimulation of the existing nerves can yield sensations that are felt as being in the place where the limb once was: Descartes to Plempius for Fromondus, 3 October 1637, AT i. 420; *Meditationes*, AT vii. 77; *Principia*, IV, art. 196. In the 1637 letter Descartes gives the impression that he had first-hand experience with the case, while the meditator says only that she has 'heard of' such cases. Albrecht von Haller, *Elementa physiologiae corporis humani* (Lausanne, 1764), 305, later listed only three published records of the phantom limb phenomenon prior to 1637, by Ambroise Paré, Wilhelm Fabricius Hildanus, and Johann Rudolph Camerarius (he did not list Descartes' descriptions). Douglas B. Price and Neil J. Twombly, *The Phantom Limb Phenomenon, a Medical, Folkloric, and Historical Study* (Washington, D.C., 1978), argue that many of the alleged miracles of limb restoration are instances of the phantom limb phenomenon, though of course not recorded as such.

44 Descartes gave the fullest account of the tubular and hydraulic mechanics of the senses in the *L'Homme*. Partial accounts are in *Dioptrique*, Disc. 4–6, and Part I of the *Passions*. He described the institution of nature in *Dioptrique*, Disc. 6, AT vi. 130, 137,and *Meditationes*, VI, AT vii. 87.

45 In the *Principia*, IV, art. 190, AT viii. 316, Descartes explains that 'the diversities of these sensations depend first on the diversity of the nerves themselves, and then on the diversity of the motions that occur in the individual nerves. Nor indeed does each individual nerve produce an individual sensation different from all the rest; rather, only seven principal kinds may be observed in the nerves, of which two relate to internal sensations, the other five to external'. This passage makes it clear that intermodal differences go with nerve groups, whereas intramodal differences in sensation (for vision, hue and intensity) depend on differences in the motions set up in a nerve. Galen also recognized seven major nerve groups (Siegel, *Galen on Sense Perception*, 7–9), but Descartes' classification differs significantly.

46 Hall attributes to Descartes the position that even intermodal differences depend on spirit flow and tubule openings alone (*Treatise of Man*, n. 134). The passage he cites is not decisive in my view, since it merely says that the same nerve (from the eye) can cause both colour sensations (red or blue) or pleasurable or painful sensations, depending on how it is stimulated (AT xi. 176).

47 The metaphysical arguments are those, mentioned above, that purport to establish that body has only geometrical properties. The arguments from simplicity and clarity are given at various points, including *Le Monde*, chs. 5–6, and in correspondence from the mid 1630s, including Descartes to Plempius for Fromondus, 3 October 1637, AT i. 422–4; to Plempius, 20 December 1637, AT i. 476–7; to Vatier, 22 February 1638, AT i. 563–4; to Morin, 13 July 1638, AT ii. 197–200.

48 AT vi. 30–1. See also *Principia*, IV, art. 198.

49 I leave aside here the question of whether Descartes exhibited tendencies toward occasionalism about mind–body interaction; see G. Hatfield, 'Force (God) in Descartes' Physics', in John Cottingham, ed., *Descartes* (Oxford, 1998), 281–310: 306 n. 87.

50 Johannes Müller, *Zur vergleichenden Physiologie des Gesichtssinnes des Menschen und der Thiere* (Leipzig, 1826), xii.

51 Müller, op. cit., 44–5. On Müller's sensory physiology and psychology, see G. Hatfield, *The Natural and the Normative: Theories of Spatial Perception from Kant to Helmholtz* (Cambridge, Mass., 1990), 152–8.

52 *Meditationes*, AT vii. 76, 145. Subjectivity as subject-dependent variability may in fact be considered in relation either to variability among species or among the individuals of a species. I here confine it exclusively to the latter. In the former case, as variability among species, subject-dependent variability can be used to support radical subjectivity, as when it is imagined that other finite intelligences might have different kinds of sense perceptions from ours: an hypothesis considered by John Locke, *An Essay Concerning Human Understanding* (London, 1690), bk. 2, ch. 2, art. 3. Between-species subject dependence does not preclude the existence of laws relating subjective states to bodily conditions within species. Nor does subject dependent variability within a species preclude such laws, as long as the variability has regular conditions of manifestation (such as distance, or jaundice).

53 *Principia*, I, art. 68.

54 *Principia*, I, art. 70, AT viiiA. 34. See also *Meditationes*, III, AT vii. 43–4. A good recent discussion of sensory ideas in Descartes is Lilli Alanen, 'Sensory ideas, objective reality, and material falsity,' in John Cottingham, ed., *Reason, Will, and Sensation* (Oxford, 1994), 229–50. Ann Wilbur MacKenzie, 'The Reconfiguration of Sensory Experience', in ibid, *Reason, Will, and Sensation*, 251–72, argues that Descartes thought colour sensations could be of no value in the investigation of nature – a conclusion that takes Descartes' epistemic indictment of the senses too far (on which, see below).

55 This is not to say that all aspects of colour sensation, or of sensation in general, are arbitrary on Descartes' account. As he explains in the Sixth Meditation, the body–sensation relation is constituted for the preservation of the body, hence, various aspects of the object–sensation mapping may serve that end. As Alison Simmons observes in 'Are Cartesian sensations representational?', *Nous* (forthcoming), it may be better for us to perceive a surface texture via colour sensation than to represent its full micromechanical structure; differing colours give us a salient way to tell objects apart. Which particular hue goes with which surface texture or particle spin may nonetheless be arbitrary in the sense that a shifted, inverted, or qualitatively different spectrum would aid discrimination just as well. The nonarbitrariness of the alignment of contrasting colours with types of objects might be argued through a careful study of colours in ecological settings – e.g. the relation of perceived fruit colours and tree leaf colours to the visual systems of the primates that eat the fruit – of a sort that Descartes did not adumbrate; see G. Hatfield, 'Color perception and neural encoding: Does metameric matching entail a loss of information?', in David Hull and Mickey Forbes, *Proceedings of the Philosophy of Science Association 1992*, 2 vols. (East Lansing, MI, 1992), i. 492–504, and Evan Thompson, *Colour Vision* (London, 1995), chs. 4–5.

56 *Dioptrique*, AT vi. 85; later Descartes claims he can 'determine what the nature of each of these colours consists in, and reveal it through experiment' (AT vi. 92).

57 *Les Météores*, Disc. 8, AT vi. 333–4.

58 *Meditationes*, VI, AT vii. 75, 81.
59 *Météores*, Disc. 8.
60 *Dioptrique*, AT vi. 132–7, 146.
61 *Dioptrique*, AT vi. 137. In *L'Homme*, AT xi. 183–8, Descartes described additional mechanisms for distance perception, including the yoking of optical convergence to a brain state (pineal tilt) which directly produces a perception of distance.
62 A standard modern textbook on colour vision, which reviews earlier developments, is Peter K. Kaiser and Robert M. Boynton, *Human Colour Vision*, 2d edn. (Washington, D.C., 1996).
63 *Dioptrique*, AT vi. 140.
64 In trying this experiment, use both eyes. Further, in considering the phenomena of size perception, it is important to distinguish between 'extent' within the visual field (which is greater for the nearer hand), and perceived size of the object, which remains nearly constant, on which see Irvin Rock, *Introduction to Perception* (New York, 1975), ch. 2, esp 38–9.
65 The most accomplished theory of the psychology of size perception up to Descartes' time was that of A. Ibn al-Haytham, *Optics, Bks. I-III*, trans. A.I. Sabra, 2 vols. (London, 1989), bk. 2, ch. 3, arts. 135–71. On the Medieval background to Descartes' work in vision, see Gary Hatfield and William Epstein, 'The sensory core and the Medieval foundations of early modern perceptual theory', *Isis* vol. 70 (1979), 363–84.
66 On the history of the constancies, see William Epstein, 'Historical Introduction to the Constancies', in William Epstein, ed., *Stability and Constancy in Visual Perception* (New York, 1977), 1–22; on the concept of perceived or apparent magnitude in the eighteenth century, see Hatfield, *Natural and Normative*, 36.
67 Antoine Le Grand (d. 1699), *Institutio philosophiae secundum principia de Renati Descartes* (London,1678); trans. Richard Blome, *An Entire Body of Philosophy, According to the Principles of the Famous Renate Des Cartes* (London, 1694), pt. 1, ch. 1, arts. 1–5 (p. 1), and pt. 1, ch. 3.
68 Le Grand, *Entire Body*, pt. 3, prefatory discourse, art. 8 (p. 77b); pt. 3, chap. 9, art. 6 (p. 87b). Le Grand divides knowledge of created substances into *somatica*, which treats of corporeal things, and *pneumatica*, which treats of spiritual things. *Pneumatica* also includes uncreated immaterial substance, or God, under the subdivision of natural theology (pt. 3, prefatory discourse, arts. 7–8, p. 77). Nonetheless, he covers the human mind in his physics.
69 Ibid., preface, sec. 3 (p. [xiv]); earlier, he said that natural philosophy comprehends 'the principles of Material Things' and also the 'Nature of Man' (p. [xii]). See also pt. 4, chap. 1, art. 2 (*Entire Body*, p. 91a).
70 Ibid., pt. 5, chap. 5, art. 3, p. 140a. In the next sentence, Le Grand supports the notion that God is the 'Ruler of Nature' by saying that he is 'present to all Things, whether intellectual or bodily.' Earlier, he included under the concept world 'every thing that can fall under our Thought', including God, men, and animals (pt. 5, ch. 1, art. 4, p. 134b). Le Grand believed his notion of God as an assisting form differed from the notion of a world soul in Plato and the Cambridge Platonist Henry More, a notion he equated with the idea that God is the soul (or substantial form) of the world.
71 Ibid., pt. 4, chap. 3, art. 18, p. 95b; ch. 9, art. 2, p. 106a; ch. 7, arts. 7–8, p. 103b. In calling the human soul a 'substantial form', Le Grand was not adopting Aristotelian hylomorphism, for he equated the human soul with a spirit 'wholly distinct from Matter' (p. 103b). The various 'forms' of extension he equated with 'modes' of matter. He also used 'form' on occasion to refer to the essential attribute of a thing (see n. 73 below).
72 Ibid., pt. 8, ch. 1, art. 8, p. 265b.

73 Ibid., pt. 4, ch. 1, art. 2, p. 91a. Le Grand also says that the union of soul and body is 'the Form of Man', that is, it is the essence of human beings to be a compound of mind and body (pt. 8, ch. 1, art. 9, p. 265b).
74 Ibid., pt. 9, chap. 3, art. 9, p. 325b.
75 Jacques Rohault, *Traité de physique* (Amsterdam, 1676), translated by John Clarke as *System of Natural Philosophy*, 2nd edn., 2 vols. (London, 1728–9), i. p. xxix.
76 Rohault, *Traité*, pt. 1, ch. 1, art. 1, trans. Clarke, i. 1.
77 Ibid., pt. 1, ch. 5, art. 7, trans. Clarke, i. 19.
78 Ibid., pt. 1, ch. 32, trans. Clarke, i. 248–57.
79 Pierre Sylvain Régis, *Système de philosophie: contenant la logique, metaphysique, physique & morale*, 7 vols. (Lyon, 1691), '*La Metaphysique*', i. 120–1.
80 Ibid., '*La Physique*', bk. 8, pt. 2, chs. 24–33; bk. 8, pt. 3.
81 Ibid., '*La Physique*', bk. 8, pt. 2, ch. 1, art. 7 (v. 347).
82 Ibid., '*Metaphysique*', bk. 1, pt. 2, ch. 4, art. 5 (1:234). Regis departed from Descartes in holding that the mind requires union with the body to have any idea of extension, including the idea of pure extension.
83 Richard Rorty, *Philosophy and the Mirror of Nature* (Princeton, 1978), claimed that from the times of Locke and Kant until the present day, philosophy's (alleged) claim to intellectual authority rested on a confusion between epistemology and psychology, which he compared to the 'naturalistic fallacy' in ethics (141); hence, though he did not use the term 'psychologism', his charge fits the classical meaning of that term, according to which psychologism is the attempt to base epistemology on psychology. Rorty reviewed earlier instances of this charge against early modern philosophy by T.H. Green and Wilfrid Sellars (140–3).
84 *Meditationes*, III, AT vii. 38–9.
85 The ultimate standard of truth according to Descartes and many others is 'the conformity of the thought with the object' (to Mersenne, 16 October 1639, AT ii. 597). But that standard cannot be appealed to for methodological or epistemological purposes in the case of metaphysical knowledge, a point that Descartes recognized in the Second Replies, when he acknowledged that one can raise the possibility that something perceived clearly and distinctly by humans could 'appear to be false to God or an Angel', only to dismiss this possibility as lacking force (AT vii. 146).
86 For a fuller discussion of these points, see Hatfield, *Natural and Normative*, chs. 2–3, and 'The workings of the intellect: Mind and psychology', in Patricia Easton, ed., *Logic and the Workings of the Mind* (Atascadero, Calif., 1997), 21–45.
87 An earlier version of this paper was presented in 1996 at Tufts University as part of the lecture series 'Descartes at 400'. I am grateful to the audience on that occasion for their questions and comments, and to Allison Crapo, Holly Pittman, and Susan Peppers for comments on later drafts.

26 Descartes and the corporeal mind

Some implications of the Regius affair

Catherine Wilson

Historians of science and intellectual historians perceive Descartes as having laid the groundwork for eighteenth-century medical materialism, which saw mental activity, moral character, and personality as functions of the human body and its interactions with the physical environment.[1] To historians of philosophy, by contrast, Descartes is the founder of the idealistic and skeptical tradition in modern philosophy. Perhaps, the stature of canonical philosophers is reflected in the degree to which they can be misinterpreted. But which is the misinterpretation?

In this paper I want to show that it is a matter of historical contingency that Descartes' name became associated with an idealistic philosophy founded upon a metaphysics of two substances. His development of this metaphysics was motivated by external resistances to his primary project, and it is perhaps fair to say that he never really understood his own metaphysics, although he defended it rigidly. The theologically contextualised two-substance theory presented in the *Meditationes* was inconsistent with Descartes' pre-existing ideas about the involvement of the brain in perception, memory, and cognition and his associated theory of human perfectibility as these are sketched in *L'Homme* and the *Discours de la Méthode*. It was only tangentially related to his earlier speculations on methodology and epistemology as these exist in the *Regulae*. Metaphysics, then, constituted an interlude during which time he tried to affix – by means of a set of careful deductions – the view of matter on which his moral-scientific researches depended within a framework of divine omnipotence and personal immortality. This accomplished to his satisfaction, he resumed his researches in the *Description du corps humain* (1647–8) and the posthumous manuscript which became the *Passions de l'Âme*. The latter work was not, as some commentators imply, an abrupt change of direction, a retreat from dualism, prompted by Princess Elizabeth's detection of an allegedly embarrassing deficiency of the *Meditationes*, the absence of a convincing account of soul–body interaction: it was simply a return to those subjects on which Descartes thought he had something truly original to say. Did Descartes then not 'believe' that he was a thinking substance whose experiences would *certainly* continue uninterruptedly if God were to separate his soul from his body, a task which just as certainly God could perform? I shall argue here that he neither believed nor disbelieved this proposition. Descartes' beliefs were about the actual world, one in which we do not experience the performance of such feats of omnipotence. And, where this world was concerned, Descartes believed that experience and some kinds of what he elsewhere describes as 'thinking' depended on his body. However, the *Meditationes* were not a *jeu d'esprit* or a tongue-in-cheek exercise; they were functional if not precisely foundational. Descartes believed that he had given proofs and arguments to support his metaphysical claims about *res cogitans* and *res extensa*, and that these proofs and arguments were good ones which had been tested and had not been refuted. This cognitive state of affairs stood in for, on my interpretation, whatever the inner Humean passion is that is properly named 'belief'.

The order of this essay is as follows: I will first discuss Descartes' original aims, and the discrepancy between them and the metaphysics of the *Meditationes*. I will then go on to describe Descartes' troubled relations with Henry Regius, the Cartesian who most clearly grasped the revisionary nature of his programme, and who, for this reason, was first supported by Descartes, then abandoned. Finally I will return to the problem of partially overlapping, partially conflicting intellectual programmes, and the problems their existence raises for attributing belief.

1 Descartes' original programme: rational medicine

Settling in Amsterdam in 1629, his biographer Adrien Baillet tells us, Descartes pursued his thoughts on 'metaphysics', considering especially how it could be treated independently from theology. He claimed not to be interested in theological subtleties and in the mysteries of eternal salvation, but in health and happiness in this world. He was already struck by the notion that the union of medicine and mathematics – that is to say the development of an orderly and intelligible account of the human body – was the key to both. To that end, he began a set of anatomical researches, buying cadavers in the Kalverstraat or 'street of veal' and bringing them home for dissection. In the 1630s and 1640s he continued to study the circulation of the blood, the formation of the foetus, the texture of the nerves and muscles, and the anatomy of the brain.[2]

Descartes' most interesting works from this period were the unpublished treatises, which later appeared as *Le Monde* or the *Traité de la Lumière* and *L'Homme,* which dealt with light, colour, corpuscles, inanimate bodies, cosmology, plants, animals and the human machine. Taken together they provided a complete system of the world, a system which its detractors did not hesitiate to designate as purely imaginary. Here Descartes distinguishes between the natural world, as it appears to our eyes as composed of different objects of characteristic shapes, sizes, colours and consistencies, and the natural world, as it exists in itself as an ensemble of subvisible corpuscles of three grades of density, flexibility and figure, but otherwise lacking in qualities. It is the action of these corpuscles on us which produces our experiences. Second, Descartes states that if God set matter into motion at the Creation, the laws He imposed on it would eventually create, without further intervention, a system of vortices containing worlds. Even living machines, which could grow, be nourished, and feel could arise out of matter without the agency of souls, forces, or forms. One of his earliest ideas, as represented in an early sketch, had been that the perfection of animal actions suggests that they have no free-will.[3] Confronting directly Galenic medicine and the scholastic philosophy of substances and powers, which represented nature as teeming with vital, intentional, and architectonic principles, Descartes portrayed matter as inert and argued that plants and animals, as purely material beings, exhibited growth, sensation, motion and reproduction through the organisation and motion of their parts.

The medical focus of these researches is apparent, and Descartes always represented mental and physical health as the overarching aim of his endeavours. In another of his early sketches he describes 'vice' as a (potentially curable) disease of the mind and comments on the relationship between mood, appetite and sleep.[4] There is a certain irony in the title of the Second Meditation, *The nature of the human mind and how it is better known than the body*,[5] with its implication that philosophers ought to restrict themselves to the study of the human mind, rather than '[engaging in the seemingly worthless task of] going through the contributions made by considering bodily things'.[6] These contributions were not regarded as worthless in the periods immediately preceding and following the publication of the *Meditationes*. In the *Discours*, Descartes tells us that he has henceforth resolved 'to devote the rest of my life to nothing other than trying to acquire some knowledge of nature from which we may derive rules in medicine which are more reliable than those we have had up till now'.[7] In the Preface to the French edition of the *Principia* he says that the principal benefit of philosophy 'depends on those parts of it which can only be learnt last of all', to wit, medicine, mechanics and morals rather than metaphysics and physics.[8] In the Preface to the *Description du corps humain,* he leads off with the claim that 'there is no more fruitful exercise than attempting to know ourselves'. He means, as the rest of the Preface makes clear, knowing ourselves as bodies:

> I believe that we would have been able to find many very reliable rules, both for curing illness and for preventing it, and even for slowing down the ageing process, if only we had spent enough effort getting to know the nature of our body, instead of attributing to the soul functions which depend solely on the body and on the disposition of its organs.[9]

Experience and action were to be illuminated and enhanced by a study of their bodily underpinnings; for it is our experiences and the consequences of our actions which make us feel well or ill, and death and disease are not mysterious external agents against which we are powerless, but names for correctible disorders in our bodily machines.[10]

Descartes' biomedical ideas, though he acknowledges the plenitude and importance of (material) fluids, exhalations, and spirits, is not what today would be termed 'physiological', for the composition and mode of action of fluid secretions and their role in maintaining and generating life remained mysterious until the nineteenth century. To replace the traditional concoctive and generative faculties, Descartes had little to offer. But when it came to what are perhaps the most salient aspects of animal life: motion and perception, which he thought he could explain in terms of pressure and movement, the originality and scope of his contributions is evident.

He was helped by Kepler's mathematical analysis of the interaction between light and the eye, which showed that the eye operated on the same principles as an optical instrument.[11] The fact that the eye of an ox can be held up and illuminated to project an image on a wall, just like an artificial lens, gave him an alternative to the Aristotelian theory that perception depends on the reception of forms without matter. As Kepler had shown, the image 'painted' on the wall was created point by point by the action of light. Descartes could now imagine that the same rays of light which painted the image as he thought onto the retina, which is part of the brain, could stimulate physical changes in the latter. The other senses could also be treated 'mechanically': sound falls on the ear, taste is a pressure on the papillae of the tongue, etc.

When he wrote the *L'Homme,* provisionally titled *Traité de l'Homme et de l'Animal*,[12] it was evident that Descartes thought that memory, imagination, desire, and sensation were performed by or instantiated in the unensouled human machine: Here is the decisive passage:

> I should like you to consider, after this, all the functions I have ascribed to this machine – such as the digestion of food, the beating of the heart and arteries, the nourishment and growth of the limbs, . . . the reception by the external sense organs of light, sounds, smells, tastes, heat and other qualities, the imprinting of the ideas of these qualities in the organs of the 'common sense' and the imagination, the retention or stamping of these ideas in the memory, the internal movements of the appetites and passions, and finally the external movements of the limbs (movements which are so appropriate not only to the actions of objects presented to the senses, but also to the passions and impressions found in the memory that they imitate perfectly the movements of a real man.[13]

The machine described is not only indistinguishable from a real man where its behaviour is concerned, so long as one does not try to engage it in conversation: it eats, breathes, moves around, and reacts appropriately to all stimuli. It is also subjectively indistinguishable from a real man from the point of view of almost all of its experiences. It gets hungry and desires things, it remembers, it feels and perceives, gets angry and affectionate, it sleeps, dreams, and wakes: it has passions and responds to external provocations. What can the machine not do? Descartes did not think he could explain how such a machine could carry on a conversation, or reason, or infer, or read books, or deal conceptually with incorporeals. He could not explain how it might consider the idea of God, supposing that God is a really existing incorporeal being, and not an imaginary corporeal being, or have attitudes directed towards propositions (doubt, affirmation, denial). But he could, he thought, explain how it lived, experienced, remembered, and reacted.

Being such a machine would be like being an animal. One might utter cries answered by other members of the species, but one would not engage in conversation, that is reply sensibly to everything that was said to one. One would not form theoretical representations, as opposed to sensory representations, of the world, or think in terms of distinguishing true from false, or infer and prove. But being an animal machine is not, from the inside, according to what Descartes says in *L'Homme* or in the *Discours,* like being a clock. When Descartes compares animals to clocks in his pre-*Meditationes* works, it is not to portray animals as insensate, but to argue that behaviour which suggests the application of a theoretical intelligence may be produced by a machine.[14] Animals are like inattentive people who are not concentrating on or thinking about what they are doing, but they do not lack awareness. In 1637, Descartes said that animals see, but not 'as we do when we are aware that we see, but only as we do when our mind is elsewhere'.[15] This suggestion that there can be experience and prudential behaviour without thought is repeated as late as 1646. 'It often happens that we walk or eat without thinking at all about what we are doing, and similarly, without using our reason we reject things which are harmful for us and parry the blows aimed at us.' Animals are compared with sleepwalkers.[16]

In the *Discours,* Descartes refers to the earlier treatise in which he has shown 'what changes must occur in the brain in order to cause waking, sleep and dreams; how light, sound, smells, tastes, heat, and other qualities of external objects can imprint various ideas on the brain through the medium of the senses'.[17] There was, I would argue, no particular problem at this stage about mind–body interaction posed by his account of memory and experience; for memory and experience on his view did not require either an incorporeal mind or a physiological or sensory soul. Descartes believed that the powers of the body far surpassed what his predecessors had assumed them to be; he wished to show how much could be accounted for without its being supposed that matter was penetrated by forms or souls.[18] For this reason, human capacities did not strike Descartes as presenting a particular problem about interaction. The human soul was originally conceived as a superaddition which made humans able to talk, entertain propositions, and prove theorems, which gave them a particularly crisp and clear consciousness of their experiences, and, above all, which enabled them to comprehend Cartesian science – transperceptual model-making. Descartes could not see any way in which the brain could confer these abilities, and this set an upper boundary to his materialism. Sensation and animal motion, meanwhile, belonged to the realm of the scientifically explicable. Even 'voluntary' motion was supposed to be explained corporeally as far as possible. This theme resurfaces post-*Meditationes* in the *Description*: '[I]n restricting our consideration to the outside of the human body, we have never imagined that it has within it enough organs or mechanisms to move of its own accord in all the different ways which we observe.'[19] And he comments further that 'it is more common for a body to be moved by another body than for it to be moved by a soul'.[20]

2 The uses of the *Meditationes*

This basic picture of the world and of the way in which sensation and animation are to be explained is dramatically subverted in the *Meditationes*, in which the author's finding is that experiences as mental attributes have nothing in common with bodily attributes. '[I]t is certain that I am really distinct from my body, and can exist without it.'[21] This 'I' is identified as 'a thing that doubts, understands, affirms, denies, is willing, is unwilling, and also imagines and has sensory perceptions'.[22] It is the inclusion of the last two attributes, imagination and perception, which is especially perturbing. For this should imply that we can be certain that sensory perceptions and imaginative acts can exist without bodies. Though such a thesis is, I suppose, logically compatible with the claim that events in bodies do in fact explain the 'purely corporeal aspects' of perception and imagination, it is somewhat baffling why or indeed how anyone would strive to defend the independence thesis while simultaneously maintaining the stunning success of a body-based explanatory programme. Additionally, Descartes appears to return to the language of the schools he had earlier scorned when he claims that he finds in himself 'faculties for certain special modes of thinking, namely imagination and sensory perception'[23] which cannot be conceived 'without an intellectual substance to inhere in'.[24]

These passages pose problems for anyone who thinks that the metaphysics of the *Meditationes* furnish in some way foundations for Cartesian natural philosophy including physics and medicine. Equally, however, Descartes' remarks about the esoteric and foundational nature of the *Meditationes* pose problems for anyone who thinks of them simply as a diversionary exercise. For Descartes told Mersenne that they contained the basis of his physics, and even suggested to his correspondents that they should not fall into the hands of the wrong people, that their content was rather risky, and that not everyone would actually be able to follow them – though those who were able to do so ought to be persuaded of their truth.[25] Nevertheless, questions about Descartes' sincerity with regard to dualism and theism have long been aired, directly by Henry More and Julien de La Mettrie, indirectly by Pascal and Leibniz. In modern times, Maxime Leroy, in a widely cited but underutilised study of 1929, described Descartes as a '*philosophe en masque*'.[26] Hiram Caton has more recently argued that Descartes' *Meditationes* was 'an elaborately contrived logical chaos', resistant to conventional methods of analysis:

> If [Descartes] sought not logical clarity but the opposite; if he set out to create an immensely dyslogical cacaphony, the *Meditations* must fall well outside the scope of conventional hermeneutical techniques.[27]

Leroy's analyses were rejected by the generation of Descartes scholars which sought to reclaim Descartes for Catholicism. In Caton's case, the notion of resistance to conventional hermeneutic techniques (meaning taking assertions for expressions of belief) doomed its reception, for if it took unconventional hermeneutical techniques to see the *Meditationes* as a logical cacophony, it was easy to argue that this cacaphonous aspect was an artifact of the odd hermeneutics, that it represented the text seen under the aspect of a posture of suspicion and a search for double meanings. As Louis Loeb noted, there were now two obstacles in the way of taking it as a serious possibility that Descartes 'intentionally misrepresented important aspects of his philosophy'.[28] First, it was difficult to advance agreed-upon criteria for interpretation which would reveal sincerity or dissimulation. Second, commentators shied away from attributing to Descartes moral character flaws, including cowardice.

In the interim, however, both the hermeneutical question and the 'cowardice' issue have been greatly illuminated by historical studies of the Galileo affair and the reception of Cartesianism, which have made it plain that (a) Descartes was prudent; (b) prudence was warranted; and (c) despite his prudence, Descartes did experience censure. Caton's suggestion that the *Meditationes* are a cacaphony needs, however, decisive rejection, and it is perhaps wrong to draw too firm a contrast between foundational and diversionary intent. In place of the metaphysics independent of theology Descartes had once expressed a hope for, his *Meditationes* offer highly presentable proofs for God's existence and the immortality of the soul which evade all major heresies. As Gaukroger has argued, Descartes required an account of immortality which would steer between two unacceptable heresies: Averroism, according to which the thinking soul is separable from the body and survives it, but is not individuated and merges with the Universal Intellect after death; and Alexandrism, which held that the corporeal faculties are instantiated in matter and cannot survive the death of the body.[29] To evade Alexandrism, the separable soul had to retain more than a faculty of rational thought. Making it the thing which 'hopes, fears, denies, wills, perceives, senses, and feels' preserved its full-blooded psychological individualism even at the cost of a contradiction with Descartes' programme of explanation. Thus, in the *Meditationes* of 1640 we are given a notion of *res cogitans* as what understands, affirms, denies and wills, and what 'also imagines and has sensory perceptions'.[30] The existence of God and full-blooded psychological immortality are offered, structurally speaking, in exchange for a permission, the legitimation and institutionalisation of a science of material bodies without forms or Aristotelian potentials, produced by experiment and untutored human reason, without benefit of the Aristotelian text. It was not simply the existence of a counter-Aristotelian science which was at issue, but its form. Descartes required a meta-theory which would show how, explanations of the origins of the world and the functioning of the human body, which his opponents saw as fanciful and strained, and objectionably Democritean and Epicurean – explanations phrased in terms of invisible micromechanisms – were correct. Ocular inspection could not by itself refute Galenic medicine – an 'empirical' view of the body as a collection of intentional organic agents – and so Descartes sought to tie his theorising instead to proof by conceptual demonstration. The *Meditationes* not only exhibit the truth-grasping mind as free from determination by sensory experience; they show how the correct parameters of explanation are settled in advance by the relationship between humans and God, and how they exclude the possibility of knowable quasi-mental agents resident in matter. It is in this exceedingly indirect sense that the *Meditationes* furnishes a foundation for Cartesian science.

To give these foundations was at the same time to divert attention from the objectionable aspects of the programme, and, by 1640, when the preparation of the *Meditationes* was underway, Descartes had shifted from emphasising the sameness of the animal and human body in their basic capacities to emphasising their difference. In the letters to Mersenne of 1640, he begins to develop the notion of 'intellectual memory' which, unlike corporeal memory, does not depend on the 'folds' of the brain. This, he says, is 'altogether spiritual, and is not found in animals. It is this that we mainly use'.[31] Descartes' newfound theological and spiritual interests, which he reliably shared with Mersenne, were demonstrably successful in smoothing the way for his ambitions to put physics and medicine on a new foundation. Shortly after Regius' appointment – which I will discuss below – Gisbert Voetius had asked Mersenne to attack Descartes as atheistic, impious, and libertine. Mersenne failed to do so. 'It is true,' he explained later, 'that you excited me a year ago to take up the pen against

Descartes, but as you never sent me more material, and now that I have read the *Meditationes'*, Mersenne said, he could not do this.[32] He explained that the *Meditationes* revealed Descartes as a good Christian, and that the work would become an ornament of the true religion. It was entirely conformable to the doctrine of St. Augustine. Descartes' concern to secure the proper reception of this work dominates his letters to Mersenne between July 1640 and November 1641.

The *Meditationes* succeeded in quieting doubts about Descartes' impiety and libertinage: the tight connection established between the possession of a psychologically fully fledged yet indestructible soul, and the knowledge of God's existence licensed the human mind as a legitimate entity capable of generating reliable scientific conclusions. Though Descartes did not seek to advance any of his physical explanations in the *Meditationes,* he seems to have hoped to stimulate a sort of process by which the epistemic authority of the meditator would infect the scientific works he planned to resume.

In attempting this exchange Descartes miscalculated on two counts. First, he did not count on Henry Regius' enthusiasm for rational medicine which led him to maintain, under the banner of Cartesianism, that all functions of the body, perception and some thoughts were corporeal, and that the soul was only 'accidentally' united to the body. Second, he overestimated the attractiveness of his offer and underestimated the tenaciousness of Aristotelianism and the degree to which the Aristotelians were invested in the hylomorphic unity of the soul and body. The Faculties at Utrecht saw Cartesianism simply as an attack on the dignity, credibility and authority of their instructors, institutions and texts, and failed to acknowledge it as a theologically superior natural philosophy. All this was brought out in the Regius affair.

3 Regius and Descartes

Regius has not been dealt with kindly or even adequately in Anglophone Descartes commentary: Descartes' 1645 view of him as a hot-headed and wayward disciple is strongly represented by Descartes' first biographer Adrien Baillet and is not often challenged. A re-evaulation is in order.

The chronology of the affair is as follows.[33] Regius was installed as a junior Professor (extraordinary) of theoretical medicine and botany in the new University of Utrecht on 6 September 1638. In contact with Descartes' ideas through Henry Reneri, a Professor of Philosophy there since 1634, he had forwarded his *Essays on Medicine,* with an appreciative note, to Descartes on 18 August 1638, when he was already confident of obtaining a new Chair in medicine.[34] Suspected of Arminianism, Regius agreed to it as a condition of his appointment that he teach nothing contrary to the received knowledge of the University and the Schools. Regius believed himself indebted to Descartes, intellectually, though not politically, for his advancement,[35] and Descartes looked fondly on him as well. In a letter of 12 September, Descartes described him as 'a good friend of mine, and, in my view, superior to all those at Leiden'.[36] Regius was a popular and charismatic figure, but he did not hold to his promise to the hiring committee. He mocked the ancients in his lectures and began 'insensibly [to] destroy the common principles of philosophy which were received in the Schools' in his representation of Cartesian physics and medicine.[37] He quickly arranged a large salary raise for himself, but also acquired detractors and satirists.[38] Descartes proudly describes Gisbert Voetius as 'bursting with rage because there is a professor of medicine in their University of Utrecht who openly teaches my philosophy, and even gives private lectures in physics, which in a few months enable his pupils to make fun of traditional philosophy as a whole', and he notes that Regius is protected by the magistrates.[39]

Several years passed, and Regius was alternately deferential and annoying to Voetius, who became Rector of the University in 1641, the year after Descartes published his *Meditationes.* In a deferential phase, Regius submitted a set of theses to the Rector for correction before publicly defending them on 17 April 1641. He made the recommended changes 'pour sauver l'honneur de la philosophie ancienne', and agreed to Voetius' suggestion that they be presented in the Faculty of Medicine, so as not to anger the philosophers. However, they were not well received. The second set of theses, on physiology, the passions, substance, quantity and movement, defended on the 5 May 1641, was construed as a profound attack on philosophy and associated medicine and mathematics, especially by Voetius. The last set of theses was defended on 8 December. Here, man (and Christ) was defined as an *ens per accidens* composed of spirit, mind, and body.[40] At the same time, Regius wrote to Descartes informing him of his pleasure at being able to defend their joint views.

The theses in question are recognizably Cartesian in the sense of *L'Homme,* though not in the sense of the *Meditationes.* The soul is said to be 'an incorporeal substance by means of which we perform cogitative actions', which are defined as those 'which we perform when we are attentive to what we are doing'. It is an immortal thinking substance which always thinks. Nutrition, respiration and generation are mechanical. Reception of sensory impressions is automatic. Universals are grasped by the imagination and are organic. There are also inorganic perceptions: the former depend on the bodily organs and involve images, the latter include the contemplation of God, the rational soul and other incorporeals.

Descartes replied twice in a row to Regius' communications and showed himself particularly anxious to dissociate himself from Regius' view that thinking is performed by the soul and body. 'For I am one of those who deny that man understands by means of the body . . .; even though the mind is hindered by the body, when it is a matter of understanding immaterial things it cannot be helped by the body, but only hindered by it'.[41] In the second Disputation, Regius had redefined Aristotelian 'form' by distinguishing between general and special form. General form is matter in motion. There is only one special form: the human soul. He stuck by his earlier claim that the human being is an 'entity by accident'. This special form, if it exists apart from the body, is a complete substance: if it is united to the body, they form a being by accident. Descartes initially seemed to go along with the entity-by-accident theory; at least, he wrote a number of letters to Regius, apparently in December 1641, stating his general agreement with all his theses.[42]

At the public defence, however, it became apparent that the entity-by-accident theory was unacceptable, for it gave ammunition to schismatics who challenged the dogma of the resurrection of the body.[43] The presentation of the thesis resulted in a kind of riot and generated a counter-tract prepared by Voetius defending substantial forms. The rejection of substantial forms, said Voetius, leads to doubt about every major plank of Christianity, including the rational soul, the Trinity, the incarnation, original sin, miracles, prophecy and demonic possession.[44] He compared Regius to several celebrated atheists and began to agitate for his dismissal from the University.[45]

Regius contacted a powerful friend of Descartes, Consul Vander Holck, who reined in the Rector. On learning of the scandal, Descartes wrote to Regius abruptly reproaching him for the stupidity of maintaining the accidental unity thesis. 'You could scarcely have said anything more objectionable and provocative.'[46] Descartes also provided him with some advice for getting and staying out of trouble. Regius ought to distinguish between (a) considering a human being in relation to the parts of which he is composed, and (b) considering the parts in relation to the whole. The human being considered as a whole is an *ens per se*. The soul is accidentally joined to the body in a sense, but not absolutely, so that it has a separate existence after death.[47] This letter is followed by a dictation from Descartes pursuant to Voetius' defense of substantial forms, about how to bring this point home, how to say what one wants to say without hitting substantial forms too hard. Equivocation, which already seems to have been present, ought to take care of the problem. This response of Descartes' is described by the admiring Baillet as 'un de plus beaux ornaments de sa douceur & de sa prudence'.[48] Voetius nevertheless found it humiliating and offensive. Descartes went on to congratulate Regius for being the centre of attention and for suffering for truth and assured him of the rightness and eventual victory of his defence of Cartesianism.[49]

Meanwhile, Regius, hurt by Descartes' dictatorial and punitive corrections, struck off on his own. In the draft of his *Fundamenta Physices*, the soul became a mode of the body. Its immortality could be known only by revelation, not by reason.[50] 'It is clear from scripture that the rational soul is an immortal substance: but this cannot be shown by any natural reasoning, and there is nothing that prevents it being *a mode of body* as well as a substance which is really distinct from it.'[51]

Descartes was infuriated. He wrote excoriating Regius:

> [W]hen I came to the chapter on man, and saw there what you hold concerning the human mind and God, not only did I find my previous judgement confirmed, but I was completely astounded and saddened, because you seem to believe such things and because you cannot refrain from writing and teaching them even though they expose you to danger and censure without bringing you any praise. . . . Lest this should rebound upon me, I find it necessary to declare once and for all that I differ from you on metaphysical questions as much as I possibly could. . . . Why was it necessary for you to mix metaphysical and theological matters in your writings. . . .?[52]

In response, Regius wrote:

> You will not be surprised at my conduct when you understand that many people of honour and intelligence have often assured me that they have too high an opinion of the excellence of your mind to believe that you do not have, at the bottom of your heart, sentiments contrary to those which appeared in public under your name. And to conceal nothing from you, several people here are persuaded that you have greatly discredited your philosophy in publishing your Meditations. . . . [T]he disputes which you have had with able people at the start of these events have only served to multiply doubts and shadows. . . . As for you Monsieur, to whom I am infinitely indebted, you will permit me to thank you for your goodness in reading my book, or, as I should say, your book, for it has really issued from you.[53]

Descartes did not reply to this letter: this was the end of their correspondence. In the published edition of the *Fundamenta Physices* of 1646, Regius stated that the mind could only think if provided with an object by the brain. At this point, Descartes repudiated him publicly.[54] Through Mersenne, his usual route for spreading information and misinformation, he sought to spread about the story that Regius had gained unauthorised access to casual drafts of his earlier work and was now defending conclusions opposite to Descartes' own. A manuscript version of a treatise on animals had fallen into his hands with woeful results.[55] As Descartes explained later,

> It is now twelve or thirteen years [1634?] since I described all the functions of the human or animal body; but the manuscript is in such a mess that I would be hard put to it to read it myself. Nevertheless four or five years ago [1641–2?] I could not avoid lending it to a close

> friend, who made a copy. . . . I begged those concerned not to show it to anyone; and I never wanted Regius to see it.[56]

The worst of it is, he complains, that 'while in matters of physics he has followed closely whatever he thought to be in accordance with my views . . . he has done just the opposite in matters of metaphysics; and in the four or five places where he treats of them, he takes exactly the opposite position to the one in my *Meditationes*'.[57] Regius' book, he complained, would make him considerably less free in communicating his thoughts than he had been. Descartes found in Cornelius Hooghelande a more obedient disciple who took his metaphysics seriously. He referred to Regius again as a 'distorter' of his doctrines in the French translation of his *Principia* (1647),[58] and, when Regius printed for distribution an anonymous placard towards the end of that year, Descartes recognized him as its author.

The placard or 'Broadsheet' states that the mind may be a substance or else it may be a mode of a corporeal substance – an attribute co-existing with extension in the same subject. It claims that 'those who assert that we clearly and distinctly conceive the human mind as necessarily (or actually) and really distinct from the body are mistaken'. Changing its tack somewhat, the Broadsheet claims that 'the human mind is a substance really distinct from the body; nevertheless, so long as it is in the body, it is organic in all its actions. Thus, as the disposition of the body varies, so the mind has different thoughts.'[59] Sense-perception is said to consist 'entirely in the perception of some corporeal motion, which requires no intentional forms'.[60] It concludes by quoting from Descartes' own dedicatory letter to the translation of the *Principia.* 'No-one acquires a great reputation for piety more easily than the superstitious or hypocritical person.'[61] Descartes pretends, in his response entitled *Notae in programma,* to have no idea what Regius is driving at. He attacks the arguments and their consistency with one another one by one, and concludes 'I blush with shame to think that in the past I have praised this author as a man of the most penetrating intelligence'.[62]

There are two interpretations of the Regius affair. One – that popularised by Baillet – is that Regius was a 'denatured disciple' whose actions were attempted parricide. To Descartes he owed his ideas and his fame, and to influential Cartesians he owed his protection. 'It is unlikely that Aristotle carried his ingratitude to his master Plato to such lengths.'[63] On this interpretation, Regius failed to comprehend Descartes' authentic thought, especially his metaphysics. He obtained unauthorised access to Descartes' works, and what he did not copy out of context he distorted. Another judgement is this one: Descartes intially saw Regius as his stalking horse, as well placed in a prominent university. His much praised 'douceur et prudence' were obtained at Regius' expense. Descartes' support for him ebbed as controversy heated up. Angered at what he perceived as

Descartes' exploitation and hypocrisy, Regius sought to lay his cards on the table, accusing Descartes of dissimulation in the *Meditationes*. The dissimulation involved Descartes' denial that the body could have corporeal thoughts, including memory, sensation, and imagination.

Interestingly, the theologians who co-authored the sixth set of Objections appeared to think it a difficulty of the *Meditationes* that Descartes had not shown that it was self-contradictory to say that thought should be reducible to corporeal motions. 'No one has been able to grasp that demonstration of yours by which you think you have proved that what you call thought cannot be a kind of corporeal motion.'[64] They note that some of the the Church fathers believed that angels were corporeal, that angels thought, and that angels and thought both were, or were products of, corporeal motions. The authors observe that dogs appear to dream and to have some awareness of what they are doing. The upshot of the objection is that they find a materialism which draws no distinction between thought and corporeal motion to be prima facie plausible and even to have a respectable pedigree, though it is wrong. They seem to think that Descartes has not done enough in the *Meditationes* to discourage this view, because they cannot accept that Descartes has explained all the operations of animals 'without invoking any sensation, life or soul', and they are willing to 'wager anything you like that this is an impossible and ridiculous claim'. They think the claim is not only impossible and ridiculous, moreover, but dangerous, for 'if the limited reasoning power to be found in animals differs from human reason, the difference is merely one of degree and does not imply any essential difference'.[65] In other words, they seem to think that the familiar posit of a hierarchy of souls: vegetative, animal, rational, is the only defense against a thoroughgoing materialism and mortalism. The beast-machine theory does not provide an appropriate basis.

Descartes' reply is confusing. He concedes that thinking and corporeal motion are typically found together. But he repeats his argument that they are separable in thought and thus really separable by God.[66] He says that they are therefore not the same in virtue of 'a unity of nature', but only the same with regard to a 'unity of composition'. He suggests that he is tempted to retract his claim that animals are machines without thought, and that he does not think that he requires this premiss to establish the immortality of the human soul. 'As for dogs and apes, even were I to concede that they have thought, it would not in any way follow from this that the human mind is not distinct from the body.' He suggests that people may be justified in concluding that 'although there is a smaller degree of reason in the beasts than there is in us, the beasts possess minds which are exactly the same type as ours'. Yet he claims to have 'proved . . . by very strong arguments which no one has refuted up to now' that animals possess no thoughts whatsoever.[67] Later in the same Reply, he claims that movements in the brain are all that is common to the sensations of animals and men; the perception of light and colour require a mind joined to the body, and distance-perception requires a rational calculation by the intellect.[68]

After 1640, it was necessary to reverse the original strategy of explaning as much as possible in the human body by corporeal motions, and to promote instead the doctrine that animals were very unlike humans. In 1642 Descartes queries whether one can perhaps explain animal movement without imagination and sentiment 'these same movements can take place without imagination'.[69] What light do these passages shed on the function of the *Meditationes*? Descartes appears to be holding up the position that the senses are not to be trusted, the basis of his intellectual approach to matter, as the only route to the distinction between the soul and body and the evasion of mortalism. Here he is in a deadlock with the tradition. For the intellectualist approach to matter, which finds substantial forms in matter unthinkable, is the edge of a wedge which leads to another heresy. As Descartes summarised Voetius' suspicions in a letter to Regius, 'if we deny substantial forms in purely material things, we may also doubt whether there is a substantial form in man, and may thus be in a less happy and secure position than the adherents of form when it comes to silencing the errors of those who imagine that there is a universal world-soul, or something similar'.[70] As Descartes tried to legitimate his scientific ideas by presenting them as inferentially connected with theological verities, so his opponents showed how his scientific ideas in fact undermined those verities.

4 The problem of belief

Did Descartes the person really believe the things he said or implied were the case in the *Meditationes* – that his experiencing soul was immortal, that God sustained him in existence from moment to moment, that the world was populated with individuated substances formerly united to bodies but now performing non-corporeal acts of cogitation and memory? Or did he believe, as Regius suggests he did, that it is the body which thinks and that our idea of God is an imaginary one?[71]

This question presupposes a more general one: is belief in fact the epistemological modality which relates philosophers to sets of metaphysical statements? For Descartes, metaphysical exactness was important in contexts of attack and defence. He showed himself a master of subtle reasoning and careful distinctions when his reputation was at stake – witness his manoeuvring around the question whether man is an *ens per se*. But in other contexts he seems not to have cared at all about precision and correctness. He often repeats his claim that one should restrict oneself to saying what people want to hear, so long as one does not absolutely perjure oneself. Metaphysics should not be practised too long or too intensively: one gets one's conclusions and stops. By 1648 he wanted discussion of his own metaphysics to stop: a fierce if unheeded warning to his future readers not to try to extract too much from them:

> A point to note is that one should not devote so much effort to the meditations and to metaphysical questions, or give them elaborate treatment in commentaries and the like. Still less should one do what some try to do, and dig more deeply into these questions than the author did; he has dealt with them quite deeply enough. It is sufficient to have grasped them once in a quite general way and then to remember the conclusion. Otherwise, they draw the mind too far away from physical and observable things, and make it unfit to study them. Yet it is just these physical studies that it is most desirable for people to pursue, since they would yield abundant benefits for life.[72]

One of Descartes' best defensive strategies was the claim that he was not an innovator. In the *Letter to Father Dinet,* he says that 'well trodden and familiar pathways are always safer than new and unknown ones, and this maxim is particularly relevant because of theology. For the experience of many years has taught us that the traditional and common philosophy is consistent with theology, but it is uncertain whether this will be true of the new philosophy.'[73] But even if Descartes' metaphysics treated of God, the soul, the world, and their causality in what he hoped would prove to be a reassuring way, its overall purpose was subordinate to his quest for knowledge which would lead to the prolongation of life and the attainment of happiness on earth. That the search for this knowledge was frankly inconsistent with the central values and doctrines of Christianity was a problem which Descartes thought, wrongly in the short term, but correctly in the longer term, that he could finesse. Like Paul Veyne's tribespeople who know that the leopard is a Christian animal who will not harm their flocks on feast days, but who watch their pastures anyway,[74] Descartes did not and and did believe in the novelty of his philosophy.

If, by contrast, questions of belief were decidable by appeal to what is called textual evidence, and if important or key beliefs were always consistent, then, once every relevant peripheral text, including the philosopher's reactions to objections and criticisms, had been surveyed and compared with the target text, his beliefs and commitments could be read off directly. Letters might be supposed to be more confidential and closer to an authentic expression of belief than treatises. And the belief-attributions of jealous colleagues or opponents might be thought to be less reliable than those of close friends or supporters. In Descartes' case, these hermeneutical rules of thumb are unreliable. Descartes used his correspondents – especially Mersenne and initially Regius – to promulgate doctrines he wanted attached to his name. The belief-attributions of enemies like Voetius concerning Descartes' lack of will to support original sin, demonic possession, the incarnation of Christ and so forth, were entirely correct. Where what is allegedly direct rather than inferential evidence is concerned, the interpreter fares no better. For any statement asserting 'I (truly, sincerely, with all my heart) believe that *p*' is only another textual element, requiring to be interpreted along with all the other evidence. Authenticity even in a philosopher naturally disposed to truth still requires a situation in which he feels free to speak, and Descartes was manifestly not free to speak; we can know this without knowing what he believed.

To know what a philosopher writing in a dangerous situation believes we require a truly testamentary statement, one made when he is beyond the reach of earthly powers and responsible to heavenly ones – if, that is, he truly believes – whatever this in turn amounts to – in the latter. (And, for the record, it is reported that Descartes forgave Regius on his deathbed.) In the absence of the truly testamentary confession we can only establish limits to thought by presenting, as boundaries and markers, certain intolerable conclusions: we cannot get closer to belief. One of these markers or boundary posts was represented for Descartes by an atheistic materialism which held that thought was generated by organised matter, that matter was self-organising, that the idea of active immaterial agency was delusory. Certainly Descartes did not, in a positive sense, believe this. But neither did he in a positive sense believe that the soul after death could continue its existence as though nothing had ever happened, as a thinking, feeling, willing, sensing, perceiving being. To hit the mark between these two absurdities would have required a precision to which Descartes did not attain, because the articulation of such an intermediate position had no direct relationship to his real interests. This intermediate region was nevertheless occupied by the repeated hints about the dependence of emotion and imagination, hence morals, on the body, and by vague references to intellectual memory as the only faculty which actually survives the death of the body.

Furthermore, Descartes was moved by the idea of himself as an intellectual being with radiant insight, and he seems to have thought of human reasoning and theory-construction, as these were exemplified in his own productions, as praeternatural: there was a strain of ecstatic enthusiasm in the young Descartes, connected with his awareness of his own mathematical abilities. This strain did not only co-exist with his materialistic tendencies; he thought of it as having led directly to his physical and physiological discoveries.[75] This sense of himself, not the alleged 'proofs' for the separability of the mind in the *Meditationes,* except insofar as these were products of the same quasi-divine thinking process, furnished an absolute conceptual barrier against any thoroughgoing materialism which would explicitly proclaim all thinking to be a function of the body.

Before he became a metaphysician, Descartes began as a physiologist who had the intention of explaining the phenomena of life – especially sensation and motion – without reference to souls or forms. He also began, however, as a reflective methodologist, who required a theory about why a rational medicine was possible. And so he adopted another intention, that of articulating an account, inspired by his experiences in mathematics, of the intrinsic independence of the truth-grasping mind from determination by sensory experience. The 'mind' thus appeared as a term in two conceptual contexts: first, as a residual – as what Descartes could not see any way to explain in physiological terms (e.g. language ability, mathematical reasoning); second, as a theoretical posit – the active agent which reasons, proves, understands, and knows, and whose knowledge is to be accepted as more authoritative than that delivered by the academic tradition, which incidentally claimed that all intellectual knowledge begins with the senses.

The 'substantiality' of the mind, that is to say, its ability to outlast the body, and its 'interactions' with the body were originally of no concern to Descartes. The first question was a theological one, which both the physiologist and the methodologist could happily leave to the theological authorities; and there were no important interactions with the body in which either the residual, symbol-using mind or the methodological truth-grasping mind seemed to be involved. Only after the construction and publication of his *Meditationes,* did Descartes apparently realise that he had constructed a puzzle about conscious experience and voluntary motion in which he was badly stuck. Yet he continued to insist to the bafflement and even outrage of every succeeding generation of philosophical readers that interaction was a trivial problem best ignored. His indifference to what they saw as a major problem for 'Cartesianism' is fully intelligible in light of the fact that Cartesian metaphysics, with its psychologically full-blooded conception of mind, was not an expression of Descartes' intellectual beliefs and commitments. Consciousness, speaking, and thinking – which is a kind of consciousness about words, symbols, or images requiring consciousness and attention – did not seem to follow from the organisation of the body and brain. But even here, Descartes was open to suggestions, so long as these suggestions were properly contextualised, that is, so long as they were discussed outside a metaphysical framework. To Gassendi, who proposed in his *Objectiones* that a faculty in the brain forms images in both animals and men, he writes, 'I do not think that . . . this solid body contributes nothing to our thoughts; it is simply that this is not at all the place to consider those topics'.[76]

Later reception proves what was latent in Descartes' work. The left wing of Cartesianism, represented by Regius and later Spinoza, whose doctrines echo many of the theses of Regius' Broadsheet, may be thought 'inauthentic' by contrast with the right or idealistic wing, represented by Malebranche and Berkeley, which builds on a platform of skepticism about matter or an outright antimaterialism. Certainly this is the implication expressed by commentators who endorse Baillet's view of Regius. But this simply shows idealistic prejudice in philosophy, which selects, where there is a fundamental ambiguity, interpretations favourable to its self-image. When Regius in his abandonment holds up his theory – his bundled package, his *Fundamenta Physices*, to Descartes as the father's true offspring, only to have the latter insist 'Not mine!' we recognize the elements of an old and poignant human story. The birth of 'modern philosophy' required a disavowal of Descartes' illegitimate offspring.

Notes

1 'Where Descartes failed, other material-mechanists, proceeding inductively and experimentally, succeeded.' T.S. Hall, *A History of General Physiology*, 2 vols. (Chicago), 1962, i. 261. See also Aram Vartanian, *Diderot and Descartes* (Princeton, 1953).
2 For an overview, see Gary Hatfield, 'Descartes' physiology and its relation to his psychology', in John Cottingham, ed., *The Cambridge Companion to Descartes* (Cambridge, 1992), 335–70.
3 'Olympian Matters,' AT x. 219.
4 'Observations', AT x. 215.
5 Meditation II, AT vii. 24.
6 Ibid., AT vii. 33.
7 *Discours*, AT vi. 78.
8 *Principes*, AT ix-B. 14–15.
9 *Description du corps humain*, AT xi. 223–4.
10 On physical and emotional equilibrium, see A.O. Rorty, 'Descartes on thinking with the body,' in *The Cambridge Companion to Descartes*, op. cit., 371–92.
11 On the decisiveness of Kepler's researches for Descartes, see J.A. Schuster, *Descartes and the Scientific Revolution* (PhD thesis, Princeton University, 2 vols., repr. Ann Arbor: University Microfilms, 1977), chs. 4–5.
12 According to Adrien Baillet, *La Vie de Monsieur Descartes*, 2 vols. (Geneva, 1970), i. 262–3.
13 AT x. 201–2.
14 *Discourse*, AT vi. 59.
15 Descartes to Plempius, 3 October 1637, AT i. 413.
16 Descartes to the Marquess of Newcastle, 23 November 1646, AT iv. 573. In the Replies to Objections of 1641, he appeals to automatic responses, such as those of people taking a fall who stick out their hands to protect their heads. Again, deliberateness rather than consciousness seems to be at issue. AT vi. 229–30.
17 Ibid., AT vi. 55.
18 As is noted by Stephen Gaukroger, *Descartes: A Biography* (Oxford, 1995), 278. See also ch. 16 in this volume.
19 *Description,* AT xi. 224.
20 Ibid., AT xi. 235.
21 Meditation VI, AT vii. 78.
22 Meditation II, AT vii. 28.
23 Meditation VI, AT vii. 78–9.
24 Ibid., AT vii 79.
25 Descartes to Huygens, July 1640, AT iii.102–3; cf. Descartes to Mersenne, 30 July 1640, AT iii 126–7.
26 Maxime Leroy, *Descartes: le philosophe au masque*, 2 vols. (Paris, 1929).
27 Hiram Caton, *The Origin of Subjectivity* (New Haven, 1973), 282–3.
28 Louis Loeb, 'Is there radical dissimulation in Descartes' *Meditations*?' in A.O. Rorty, ed., *Essays on Descartes' Meditations* (Berkeley, 1986), 243–70: 243.

29 See Gaukroger, *Descartes*, 348.
30 Second Meditation, AT vii. 28.
31 Descartes to Mersenne, 6 August 1640, AT iii. 143; cf. the two letters to Mersenne preceding it.
32 Baillet, *Vie de Descartes*, ii. 143.
33 I follow the exposition, though not the assessment, of Theo Verbeek, *Descartes and the Dutch* (Carbondale, 1992), 13–17.
34 Regius to Descartes, 18 August 1638, precis in AT ii. 305–6.
35 Baillet, *La Vie de Monsieur Descartes,* ii. 7.
36 Descartes to De Beaune, 12 September 1638, AT ii. 379.
37 Baillet, *Vie de Descartes*, ii. 34.
38 Ibid., 24.
39 Descartes to Mersenne, 11 November 1640, AT iii. 231.
40 See the editors' introduction at AT iii. 368. According to Baillet, the doctrine of unity by accident was associated with Nicolaus Taurellus and David Gorlaeus (*Vie*, ii. 145). Gorlaeus' posthumously published works (Leyden, 1620) defended atomism and 'may be considered a sharp criticism of the usual *cursus philosophicus*'. Lynn Thorndyke, *History of Magic and Experimental Science,* 8 vols (New York, 1931), vii. 379.
41 Descartes to Regius, AT iii. 375.
42 Descartes to Regius, AT iii. 454.
43 Verbeek, *Descartes and the Dutch*, 17.
44 Baillet, *Vie de Descartes,* ii. 146.
45 Ibid.
46 Descartes to Regius, December 1641, AT iii. 460.
47 Ibid.
48 Baillet, *Vie de Descartes,* ii. 152.
49 Ibid., 154.
50 Verbeek, *Descartes and the Dutch,* 52.
51 Baillet, *Vie de Descartes*, ii. 270.
52 Descartes to Regius, July 1645, AT iv. 249–50.
53 Regius to Descartes, 23 July 1645, AT iv. 255.
54 Verbeek, *Descartes and the Dutch,* 52.
55 It is not clear whether Descartes planned to write a separate treatise on animals, as Baillet suggests (*Vie*, ii. 272–3) or whether the revisions to what was published as *L'Homme* incorporated the material from the 1634 *Traité de l'Homme et de l'Animal,* as is argued by Bitbol-Hespériès *Le Monde & l'Homme* (Paris, 1996), xlvi–xlix).
56 Descartes to Mersenne, 23 November 1646, AT iv. 566–7.
57 Descartes to Mersenne, 5 October 1646, AT: iv. 510.
58 Descartes, Preface to the *Principles of Philosophy*, AT ixB. 19.
59 Regius, 'An Account of the Human Mind, or Rational Soul, which Explains what It is and what It can Be.' AT viiiB. 343–4.
60 Ibid., 346.
61 Ibid., 346.
62 Ibid., 364.
63 Baillet, *Vie*, ii 271.
64 AT vii. 413.
65 *Replies to Objections* VI, AT vii. 414.
66 AT vii. 425.
67 Ibid.
68 AT vii. 437–8. How animals can perceive distances is thus an unsolved problem.
69 Descartes to Giboeuf, 19 January 1642; AT iii. 479–80.
70 Descartes to Regius, January 1642; AT iii. 502.

71 On God as imaginary idea, see Regius' Broadsheet, Nos. 9. 12,13, 14, 15: AT viiiB. 344–5.
72 Descartes, 'Conversation with Burman', 16 April 1646, AT v. 165.
73 Letter to Father Dinet (1642) AT vii. 579. Voetius accused Regius of informing on him to give Descartes material for this letter; see Baillet, *Vie de Descartes* ii. 179.
74 Paul Veyne, *Did the Greeks Believe in Their Myths?'* tr. Paula Wissing (Chicago, 1988), xi. Veyne's is a remarkable study of 'the plurality of modalities of belief'.
75 As the remarks to Burman about being made in God's image suggest. AT v. 154–6.
76 Descartes, *Replies to Objections V*: AT vii. 355.

27 Perrault's criticisms of the Cartesian theory of the soul

John P. Wright

Claude Perrault's *Essais de Physique*[1] were published in two parts in 1680 and 1688, an important time for the spread of Cartesianism in France. Perrault himself espoused a form of mechanism in physics, and put forward mechanical accounts of gravity and cohesion. He even wrote of the mechanism of animals.[2] Nevertheless, in his physiological writings Perrault revealed himself as an antagonist of the Cartesian theory of the mind or soul. Indeed, while he never directly identified his opponents, his discussions of the soul systematically criticise the doctrines of Descartes and followers such as Malebranche. By studying Perrault's ideas on the soul, we not only become acquainted with a curious historical alternative to the Cartesian theory, but we also can develop a clear idea of what appeared controversial in that theory to an important contemporary. The result is that the Cartesian theory of mind takes on a very different look than it does from the perspective of the twentieth century.

Perrault's theory of the soul first appeared in 1680 in the papers 'Du Bruit' and 'De la mechanique des animaux' in volumes 2 and 3 of the *Essais de Physique*. It was further developed in 'Des sens exterieurs' and 'Du mouvement des yeux', which were published posthumously in the fourth volume in 1688. We know that a major component of the theory, namely the idea that 'the soul is spread throughout the body (*l'âme est également par tout le corps*)' was formulated by Perrault near the end of 1675 or beginning of 1676, for Leibniz refers to this in his notebook as 'l'opinion de Mons. Perrault'.[3] It is a reasonable assumption that this view was discussed by the two philosophers, since Leibniz was in Paris in those years and Perrault's views on the soul had not yet been published.

The mid 1670s were crucial years for the spread of Cartesian ideas. Malebranche's *De la Recherche de la vérité* was first published in 1674. Quite apart from its philosophical theology, it contained not only a strong endorsement of the animal machine doctrine, but also a vivid discussion of the mechanical operations of the brain required for sense perception and imagination. The book which inspired Malebranche's interest in Cartesianism, namely the posthumous publication by Clerselier of Descartes' *L'Homme* and *La Description du corps humain*, had appeared just ten years earlier in 1664. In *L'Homme* there were vivid speculations about the operations of the brain, accompanied with claims about the mechanism of processes that for most contemporaries would have been considered to belong to the mind or soul. Among the psychological processes which Descartes attempted to model in a purely mechanical way were memory[4] and imagination, appetite and passions, and the automatic behaviour which was supposed to result from them.[5] As we shall see, there is good reason to think that these accounts were in the background as Claude Perrault developed his own theory of the soul in the 1670s.

Another major theme of Cartesianism was that the soul is not involved in the vital operations of a living body, even in human beings. Descartes' aim in his *L'Homme* was to describe the functions of the human body 'which may occur in us without our thinking of them, and hence without any contribution from our soul'.[6] In the preface to the *Description,* Descartes wrote that:

> Our soul, in so far as it is a substance which is distinct from the body, is known to us merely through the fact that it thinks. . . . The other functions which some people attribute to the soul, such as moving the heart and arteries, digesting the food in the stomach and so on, do not involve any thought, they are simply bodily movements.[7]

The animal machine doctrine should, I believe, be seen as an extension of this idea: Descartes' central aim was to show that the basic operations of life and self-preservation, including those related to the external environment, can take place purely automatically without a soul. The soul itself plays no fundamental role in keeping an animal alive.

Similarly, Malebranche wrote against those who 'falsely attach the word *soul* to the idea of producer and guardian of the body'.[8] The soul is not responsible for the digestion of our food, nor for the movement and heat of our blood. Nor is it 'spread in our members in order to convey to them feeling and life'. It is impossible for the soul to do these things because 'it does not even know how the body it animates is composed'. Malebranche does not deny that there is an intelligence controlling animal bodies. 'But this intelligence . . . is distinct from animals, as the intelligence that arranges the wheels of a watch is distinct from the watch'.[9] For Malebranche, the intelligence, knowledge and even the force which drives the bodies of men and animals is to be found in the Deity who constructed these bodies, not in the organism itself.

Third, it is a major theme of Cartesianism that all thought is conscious thought. In explaining the term 'thought' Descartes wrote that he understood it 'to include everything that is within us in such a way that we are immediately aware of it'. The original Latin which is translated here reads '*immediate conscii sumus*'.[10] Descartes goes on to stress in particular that the operations of the will are thoughts in this sense.[11] In his *Passions de l'Âme,* Descartes denies that there can be any conflicts between different volitions in the soul itself (§47) and ascribes any actions opposing our conscious will to the mechanics of the body (§13).

Finally, scholars stress the centrality of the substantial union of soul and body in the Cartesian conception of the human being. This theory is closely tied up with the account of 'nature as teacher' in Descartes' Sixth Meditation, and with the closely related theory of 'natural judgments' as developed by Malebranche.[12] What is central in both theories is the idea that the union of mind and body is based on an original connection which was established by God or nature for human survival.

Perrault takes issue with each of these Cartesian doctrines, replacing them with doctrines of his own. In the first place, he denies that the soul requires any physical organs to perform its functions of memory, imagination, and reasoning. The soul is non-mechanical for Perrault in a way that it never was for Descartes and Malebranche. Second, Perrault denies that life can occur without a soul. Animals are not automata, nor, even more importantly, can the basic organs of life dispense with the soul for their operations. For Perrault, the basic function of the soul is to preserve and protect the body. It is the principle of life. Third, Perrault rejects Descartes' view that all thought is conscious and that all its volitions must be conscious modes of thought. For Perrault, most of our thoughts are unconscious and the explanation through which they become unconscious, is psychological. Perrault is opposed to the Cartesian view that thought is the essence of the soul. His conception of the soul is more closely tied with the knowledge it possesses for its own survival. Finally, the union of soul and body takes an entirely different form for Perrault than it does for Descartes and Malebranche. Sensation, which lies at the root of the Cartesian account of the union, is given an entirely different analysis by Perrault. Moreover, the union of soul and body for Perrault is fundamentally a voluntary union, which, while it has survival as its goal, is under the rational control of the soul of the individual organism. In general, Perrault's account of the connection of the soul and body is based on individual knowledge and will in a way that Descartes and Malebranche reject.

1 Criticism of the mechanical descriptions of the functions of the soul

The foundation of Perrault's 'New system . . . of the interior senses'[13] is that 'the soul only makes use of corporeal organs in order to be instructed by the exterior senses'.[14] The soul only uses the body in order to receive exterior impressions. By the 'interior senses' Perrault means the functions of imagination, judgement, and memory,[15] as well as reasoning. According to him, these functions 'take place independently of corporeal organs'.[16]

Perrault argues for this conclusion in a series of steps. First, he claims that the brain is not required for sense perception, and that sense perception takes place at the periphery of the body. Second, he presents a series of arguments to show that memory is not explained by traces left in the brain by the motions of animal spirits, and that it is implausible to claim that the actions resulting from memory are purely automatic. Finally, he argues that reasoning, even in animals, is not a process that can be explained mechanically.

Let me begin, as Perrault does, with his discussion of sense perception. In denying that sense perception takes place in the brain Perrault takes issue with a central Cartesian doctrine. It is a major thesis of Descartes, defended in the fourth Discourse of the *Dioptrique*,[17] as well as in Part 4 of the *Principia*, 'that the soul only feels insofar as it is in the brain'.[18] Elsewhere, in *L'Homme*,[19] as well as the *Passions*,[20] he located the function of sensation more specifically on the surface of the pineal gland along with imagination and common sense. Descartes also gave a suggestion about how he thought motion could be transferred from the peripheral organ of sense via the nerves to the pores surrounding the pineal gland. Essentially, he thought of sensation as occurring through the pull of a kind of bell rope which hangs in the centre of the nerve when it is filled with animal spirits.[21] In this way, motions from the external sense organ could be transferred immediately to the brain.[22]

There is good reason to think that Perrault is taking issue with this Cartesian theory when he writes that he does not understand 'how this propagation of motion and agitation caused by sensation can be transferred to the base of the brain'.[23] When he questions the necessity that images pass from the external organs to the base of the brain,[24] he is not thinking of *images* as the 'intentional species' of the scholastics criticised by Descartes in Discourse 1 and 4 of the *Dioptrique*. Rather, Perrault wonders how the mechanical theory of transfer of motions can ever explain sensation. After criticising a theory which hypothesises that such motions are transferred by the animal spirits themselves he writes:

> I do not find less difficulty in (the theory of) the agitation of nervous fibres because, for example, in sight the communication can only be made by straight lines, and the optic nerves are oblique to the rays of light which enter through the eye.[25]

It may well be Descartes' own theory of sensation which he is thinking about here. The mechanisms proposed by the Cartesians to explain sensation simply will not work.

Perrault discusses the difficulties of explaining how the impression could ever travel to the brain in any state that would accurately encode information from the external senses. He points out that the external organs themselves are delicately contrived to receive the motions of the external object and that the nerves which travel to the brain have an entirely different structure than the organs of sense: for example, being transparent, the parts of the eye seem perfectly suited to receive the motions connected with light, while the nerves have a structure which seems in no way suited to the transfer of these motions.[26] What better place for the soul to receive these motions than in the eye itself? Perrault's own theory is that the brain is merely required to secrete animal spirits which must travel through the nerve to the external sense organ for sensation to occur.

Descartes had argued that the fact that an injury to a nerve prevents sensation shows that the motion which must be transferred to the brain required for sensation to take place is impeded.[27] Perrault takes issue with this on the basis of a careful study of the psychological phenomena: the way the loss of sensation occurs, shows that, on the contrary, the flow of animal spirits towards the organ of external sense is only slowly cut off.[28] If sensation required the transfer of an impression from the external organ to the brain, the ligature would immediately prevent sensation; however, the loss of sensation occurs slowly, just as one would expect from the gradual decrease of the quantity of animal spirits in the organ of sensation.[29]

Again, according to Descartes, the fact that a person who has lost a hand continues to feel pain in place where the hand once was shows that 'the pain of the hand is not felt by the soul in so far as it is in the hand, but insofar as it is in the brain'.[30] Perrault answers that this only shows the strong effect of the customary judgments that we make in matters of sensation; since these judgments are made habitually, they fail to be corrected even when experience shows us that the facts are entirely different.[31] We shall see that habit plays a fundamental role in Perrault's theory of the soul.[32] In general, where the Cartesians were inclined to present a psychophysiological explanation of mental functions (or in this case, their loss), Perrault replaces it with a purely psychological one. The upshot of Perrault's argument here is not merely that Descartes' corporeal explanation for the phantom limb does not work, but that, even for him, a further psychological explanation for the false judgment is needed.

The rejection of corporeal explanations for the functions of the soul becomes even clearer when Perrault turns to *memory*. According to Perrault, what has led philosophers to suppose that sensation occurs in the brain is that they believe that images must be transported to a storehouse in the brain in which they are conserved for purposes of memory.[33] But he stresses that even if the idea that images can be imprinted corporeally in the brain is conceivable in the case of the sensations of sight, it is not in the case of other sensations like sounds and tastes which themselves have no shape.[34] The representations of memory are only metaphorically like paintings or like the imprint of a seal, and it is only by equivocation that one takes these two different ways of representing one for the other.[35]

According to Perrault, memory represents many things to an animal which could not be represented by corporeal images.

Perrault may well have been responding directly to a passage in Malebranche's *Recherche de la vérité*. Malebranche wrote that:

> For the explanation of *memory* it is sufficient to understand this truth well: That all our different perceptions are attached to the changes occurring in the fibres of the principal part of the brain, where the soul resides more particularly; because assuming this single principle, the nature of memory is explained.[36]

Perrault's response to this doctrine that memory is explained by changes left in the substance of the brain is clear. After rejecting the Cartesian theory of memory Perrault writes, that 'there is nothing as useless and pretentious' as to try to explain everything mechanically, especially where 'everything is equally obscure and unknown' as it is 'in all that concerns the soul'.[37]

Perrault is even more critical when he turns to a consideration of the purely automatic behaviour which is supposed to result from the internal senses.[38] Once again, he concentrates on memory. He discusses an attempted mechanical explanation of the way memory traces in the brain might cause an animal to find its way back home when it has once travelled the route in a single direction. According to the account, as characterised by Perrault, when a horse on the way home, sees the road a second time, this opens

> the same traces which have already been imprinted by the first view (of the road), which it had in coming, and opens the same passages to the motive spirits in the limbs, and gives them a similar movement, which makes the animal return in the same way as it did when it came.[39]

But Perrault points out that the original traces of the image of the road from Couchant to Levant will only dispose the legs of the horse to travel from Couchant to Levant; they will not be the appropriate traces for the horse to return from Levant to Couchant because these places are presented to the eyes of the horse in an entirely different way when he returns. They will be new traces in his brain, which have no relation to the first set of traces.

Perrault also turns to experimental evidence to show that memory causes action quite independently of any traces in the brain. He describes how a viper which was being dissected in the Bibliothèque du Rois, 'after its head was cut off and its heart and the rest of its entails were removed . . . crawled in its usual way, and passing a corner of the garden, sought out a pile of stones, in which it went to hide'.[40] Pointing out that the viper must have been able to use the memories of touch, in order to crawl, as well as to seek for shelter in an appropriate place, he notes that ‘it is impossible to deny that memory had some part in this action’.

Perrault goes on to discuss the use of *reason* in animals, in particular, the reasoning of hunting dogs in tracking their prey, as well in retracing their way back to their master through the sense of smell after they have been taken to a place at some distance from home.[41] He insists that such reasoning – requiring, for example, that dogs sense their own odour, judge that this odour signifies that they passed this road in being taken away from their master, and conclude that they can find their way back to him ‘in following the same road’ – cannot be produced mechanically.[42]

2 The soul as the preserver and protector of the body

In the Foreword to his 1680 essay ‘*De la mechanique des animaux*’ Perrault said he was addressing those who ‘have heard it said that most animals are pure machines’.[43] He gives notice that by ‘animal’ he understands ‘a being which has feeling, and which is capable of exercising the functions of life by a principle which is called a soul’. Thus at the very outset he identifies the soul, not as a thinking thing, but rather as the principle of life. He argues that the soul is required to move and direct all the parts of the body. Perrault does not deny that the body is a machine and that the organs of the body must be described mechanically just as one describes any other parts of nature. However, he insists that, in a living body, the soul is the cause ‘of the action of each of the parts of the machine’ and that ‘the whole machine . . . requires that the soul move and direct it’. A machine, for Perrault, is an instrument, not an automaton.

In ‘*De la mechanique des animaux*’ Perrault says he is content merely to describe the mechanics of the parts of animals, and he does not make any claim ‘to dig deeper in searching for the principle which makes them act’.[44] Indeed, he states of the mechanism of the parts that ‘it is the only thing in nature which we are permitted to know’. However, in 1688 at the beginning of the essay ‘*Des sens exterieurs*’, he characterises the soul in a more positive way. He notes that while we would be wrong to explain the movement of a flower toward the sun or the attraction of iron by a magnet by ‘a feeling which carries things to seek what they love,’ this does not mean that ‘it is useless to have recourse to other principles’ to explain the movement of animals.[45] The other principles which he appeals to are ‘those of feeling (sentiment) and knowledge’. Perrault goes on to contrast plants and animals in the following way: while plants merely respond to movements which are imprinted on them through ‘the structure of their passageways’,[46] the internal principle which we call a soul in animals is able to seek out what is beneficial and flee what is harmful. In order for this to be possible it must be ‘capable of knowing the good and bad qualities of things’.[47] In general, ‘in an animate body . . . everything is done with a prudence and discretion which it would not be easy to attribute to a machine'.[48] And while a machine acts necessarily, always following a certain order which depends on the structure of its parts, it appears 'that an animal makes use of these dispositions in a way that it is the master of them'.

Perrault's conception of the soul or mind seems to be tied up with its utility for the survival of the organism. This, I think, becomes clear in the final paper in which he discusses the soul, '*Du mouvement des yeux*'. Here Perrault considers the fact that we move our two eyes together and indeed, appear not to be able to do otherwise. According to Perrault, this phenomena is explained not by any physical changes in the muscles of the eye, but rather 'in the necessity and utility of this uniformity of movement, which prevents our two eyes from seeing objects double'.[49] In our infancy, according to Perrault, we made a decision to operate our two eyes together in order to form a single image. Perrault notes that, while final causes should not be looked for in physics, they are admissible here where one clearly has 'a voluntary action which is directed by an agent capable of knowing the goal'. What was originally a voluntary action, performed with attention, has come to appear involuntary because the soul 'has imposed on itself this law founded on the great utility which the animal attains through this sort of movement'. This is similar, according to Perrault, to the law which it imposes on 'the heart and other parts which are called natural and involuntary'. Indeed, Perrault insists that there is no absolute distinction between voluntary and involuntary movement. The actions performed by habit are done with a will 'that is confused and . . . which we do not apperceive, but which presides over the actions, which are of the first necessity (and) which contribute directly to our conservation'.[50] The fact that we cannot easily oppose such an unconscious will through a conscious one is due to the fact that it is useful for our survival. Nevertheless, he points out that there was a Roman gladiator who could stop the supposed reflex motion of his eyes and that it would not be strange 'if it occurred one day that a man could have the power to stop the movement of his own heart or suspend at will the action for the parts which would result in nutrition or the distribution of food'. For Perrault, the soul has as its principal function the voluntary conservation of the body to which it is joined.

3 Perrault's theory of unconscious thought, reasoning, and volition

This brings us to the core of Perrault's philosophy of the soul, the claim (to speak somewhat loosely at first) that the soul operates through unconscious thoughts, unconscious reasonings, and perhaps, most importantly, unconscious volitions. He recognizes that some will find surprising his claim that a horse or dog can go through a reasoning process, for the process which he is ascribing to animals is not even understood by most human beings. Perrault answers this objection by observing that 'it is not necessary to know what thinking and reasoning are in order to think and reason'.[51] Indeed, most human thought and reasoning takes place without any apperception. Here again one finds Perrault directly taking issue with a major principle of the Cartesian theory of the soul. For Descartes, 'we cannot have any thought of which we lack actual knowledge at the moment it is in us'.[52]

Perrault's expression for what I have called unconscious thought is 'neglected and confused thought (*pensée negligée & confuse*)'.[53] He says such thoughts are insensibles and that 'we do not have any apperception of them (*nous ne nous en appercevons point*)'. Elsewhere he writes that 'we are often ignorant of most of the functions of our soul'.[54] So it is not entirely misleading to call such thoughts and actions of the soul unconscious, though this is not a term which Perrault employs.

However, it would be less accurate to identify Perrault's contrasting category, 'explicit and distinct thought (*pensée expresse & distincte*)',[55] solely with conscious thought. He notes that explicit thoughts are required 'for things to which we apply ourselves with care',[56] and which differ only from the confused thoughts in that they involve 'reflexion'.[57] But he includes among such thoughts not only those which we would call conscious, but also those impressions one has when one is ill with a fever and must attend to in order to affect the 'maturation and rectification of the corrupted humours' of the body.[58] Perrault also believes that the soul of a baby has explicit and distinct thoughts at the beginning of life, when he is learning to operate the body machine in which he finds himself. In identifying such thoughts as explicit and distinct he could not have intended that they be actually *conscious*.

What makes these thoughts 'explicit and distinct' is attention. Perrault argues that while we normally have a number of thoughts at one time 'we can only attend to a single one'; what draws our attention to a certain thought is the fact 'that it has, or at least appears to have a certain novelty' which 'obliges us to consider and examine it'.[59] In the case of the thoughts of our internal bodily state, the novel conditions which draw our attention are those which concern matters which we must reflect on for our survival. Thus, 'in the first days of life' a baby must give 'a great deal of attention in order to study the artifice and uses of all the muscles, to adjust his breath for the voice, and the body heat for the concoction of food'.[60] The performance of these activities at the beginning of life must be accompanied with the greatest attention.[61]

However, when such thoughts lose their novelty and the actions which accompany them become habitual they are still under the control of the soul: they are performed with neglected and confused thoughts. Habit, on Perrault's account, causes us to forget the explicit and distinct thoughts which we first had when we performed these inner actions. Yet he still insists they must be performed with knowledge and hence with thought. We are 'ignorant of most of the functions of our soul although they all lie within our knowledge'.[62] He asks us to 'reflect on the many things that we have forgotten in the same way'.[63] After one has learned a foreign language, one forgets the rules of grammar which one first had to attend to in order to learn it; yet must still have implicit knowledge of those rules in order to continue to speak the language. Similarly, one forgets the fingering chart one has used to learn pieces on a musical instrument once one has mastered those pieces[64]; yet one retains knowledge of the fingering one must use.

Perrault holds that even though we are not aware of the individual thoughts we have when we perform such habitual activities, such thoughts are as articulated as the original attentive thoughts: 'this confused thought is performed with a reasoning which is composed of all its parts'.[65] On Perrault's view, the skilled pianist who has mastered a complex piece still has thoughts of all the individual motions of her hands and fingers which she originally learned.

Perrault's theory of habitual action stands in direct contrast to that of the Cartesians. In the *Recherche*, Malebranche explained habits by the physical changes which arise when two traces in the brain are imprinted at exactly the same time. No thought is required for the formation and repetition of habits. They depend entirely on mechanical changes in the brain:

> . . . It is enough that many traces were produced at the same time for them all to rise together. This is because the animal spirits, finding the path of all the traces at the same time half open, continue on them since it is easier for them to travel those paths than through other parts of the brain. This is the cause of memory and of the bodily habits we share with the beasts.[66]

Malebranche explained the difficulty we have 'moving our fingers with the speed necessary for playing musical instruments, or in moving the muscles used in pronouncing a foreign language' by hypothesising that the pathways are not yet formed.[67] However, 'little by little the animal spirits open and smooth these paths by their continual flow, so that in time they find no more resistance' and bodily habits come to be developed. Malebranche wrote that 'it is in this facility the animal spirits have of flowing into the members of our bodies that *habits* consist'.

When an action becomes habitual for Malebranche, it is performed mechanically, not requiring any thought on the part of the subject. One can only find it remarkable that two contemporary seventeenth-century philosophers would have had such different explanations of such a fundamental fact of human psychology. Once again, we are reminded of the centrality of psychophysiological explanation for the Cartesians, and its complete rejection by Perrault. But we should also be struck by the latter's insistence that habitual actions are performed by way of unconscious thoughts, reasonings and volitions.

4 The soul/body union

Finally, let me turn to Perrault's profoundly anti-Cartesian view of the way soul and body are related. There were, let us remind ourselves, two sides to what Descartes called the substantial union of soul and body. One concerned the soul's receptive role in sensation, taken in the widest sense. The second concerned our ability to move our body through an act of the will.

First, consider sensation. In the sixth Discourse of the *Dioptrique*, Descartes warns his readers not to think that sensation takes place by means of some sort of image, 'as if there were yet other eyes within our brain with which we could perceive it'.[68] Rather, the movements which constitute the image of the object in the brain 'are ordained by nature to make it have such sensations'. In the Sixth Meditation, Descartes contrasts the natural union of soul and body through sensation with an intellectual connection in which I understand the mechanical changes in my body. He focused on the sensations of pain, hunger and thirst:

> Nature also teaches me, by these sensations of pain, hunger and thirst and so on, that I am not merely present in my body as a sailor is present in a ship, but that I am very closely joined and, as it were, intermingled with it, so that I and the body form a unit.[69]

For Descartes, these sensations 'are nothing but confused modes of thinking which arise from the union and, as it were, intermingling of the mind with the body'.

In the Sixth Meditation and *Passions de l'Âme*, he went on to elaborate on this *natural* connection between the sensations in the soul and the motions of the body. In the *Passions*, he says that the soul itself is of such a nature that 'it has as many different perceptions as there occur different movements in this gland'.[70] In his Sixth Meditation, he writes that the sensation which occurs in the mind is 'the one sensation which, of all possible sensations, is most conducive to the preservation of the healthy man'.[71] Thus, for example, if my body is healthy, I feel a pain in my foot rather than in my brain because 'there is nothing else which would have been so conducive to the continued well-being of the body' than that sensation which I am made to feel.[72] Descartes ascribes this natural linkage of the soul and body to 'the immense goodness of God', a notion which became even more central in the account of the linkage of soul and body given by Malebranche.

It is important to consider carefully just how these Cartesian notions are transformed in Perrault's analysis of sensation. The first thing to note is that sensations such as pain, which for Descartes are normally 'confused modes of thinking',[73] are, for Perrault, thoughts which are 'explicit and distinct'.[74] These are the thoughts which we attend to. Moreover, for Perrault, there are intellectual thoughts which necessarily accompany our sensations of pleasure and pain. In his essay 'Des sens exterieurs', Perrault writes that 'the soul apprehends the presence of causes capable of bringing harm or benefit to the body of which it has knowledge'.[75] It does so by way of a neglected and confused thought which in turn gives rise to the '*expresse & distincte*' thought of the sensation itself:

> . . . The first effect which the object produces [is] to excite the confused thought in the way that it does in all the natural functions; but because in the causes of pain or pleasure . . . [there is] something out of the ordinary, the confused gives rise to the explicit thought and is found accompanied with a reflection by which one knows what one senses.[76]

Perrault's idea is that in the case of pain we have an intellectual understanding of the damage which is occurring in the body (though only by way of unconscious thoughts), and it is this understanding which is the source of the explicit and distinct thought of pain. Pain, far from being the result of a natural connection with the mechanical changes in the body, is the result of the unconscious intellectual understanding which the soul has of the state of the body. For Perrault, unlike Descartes, there are indeed other eyes in us which perceive what is happening in our bodies, and these eyes of the soul are required in order for us to make 'a resolution to defend ourselves from what is disagreeable and enjoy what is agreeable'.

For Perrault, unlike the Cartesians, the soul is 'a knowing being' which 'must first and foremost know what happens to it' in virtue its direct union with subtle parts of the body.[77] For Descartes and Malebranche, while there are certain sensations which arise in the soul, when there are certain mechanical changes in the brain, these sensations are not correlated with any perspicuous knowledge of what is happening in the body. It is true that I feel pain in the foot, but this comes about because of a connection with the mechanism of my body established by God or nature, not because I have any understanding of what is going on in the foot. Indeed, this is the very thing denied by the Descartes in the Sixth Meditation.

In 'Des sens exterieurs', Perrault appeals to 'the modern philosophers' in support of the idea that 'knowledge, or perception' is 'a modification of the soul . . . which happens to it in conformity with the changes in the manner of being of the body which it animates'.[78] But the distance between his view and that of the Cartesians becomes clear when he goes on to ask why we do not 'apperceive all the movements which occur in the particles which compose the part of the body to which it is united'. For the Cartesians, this would be like asking why we do not perceive the inside of our brains when we sense external objects! This is not a problem for them because the soul/body union is not based on any knowledge which we have of the actual mechanical constitution of our bodies. For Perrault, on the other hand, we have knowledge of the internal constitution of our bodies, which has become unconscious through custom and habit. For him, the soul is essentially linked to the body by way of such knowledge, and without it survival would be impossible.

The connection between mind and body for Perrault is not only rooted in the rational knowledge which the soul has of the body; it is entirely dependent on the will. The movement of my heart, while it appears to be necessary, is really 'in its own nature . . . absolutely free'.[79] It is performed by an organ which is completely under the control of the will. Perrault claims that the supposed necessity which prevents us from controlling our heartbeat with an explicit volition is really self-imposed. He likens it to a resolution formed by a person who has a precious object which she has decided to hold on to, even at the risk of her life; even if she tries to overcome this resolution, when she is attacked by robbers, she is not able to let go. The difficulty in letting go of the object is not due to any change in the structure of the organs her body, but in the firmness of her original resolution. Similarly, at the beginning of my life I formed a resolution to keep my heart beating, and it is this resolution which makes it difficult for me to consciously will to change my heartbeat now.

Perrault's conception of the will is, in fundamental respects, different from that of the Cartesians. For them, the primary connection between action of the will, and the movements of the body which follow from them is, like the connection between sensation and bodily movement, a natural one. In the *Passions*, Descartes stresses that the bodily effects of any volition are often indirect and depend on the way 'nature or habit has joined certain movements of the gland to certain thoughts'.[80] We cannot merely will to widen the pupils of our eyes when we concentrate on doing so; on the other hand, we can effect this change in the body by desiring to look at a distant object. The reason is that 'the movement of the gland . . . has been joined by nature with the volition to look at distant or nearby objects, rather than with the volition to enlarge or contract the pupils'. The importance of the original or natural connections between the thoughts which we have when we will some action of our body, on the one hand, and the movements of the body, on the other, are even clearer in Malebranche, who attributes such connections to God. The upshot of both theories is that our ability to move our bodies by volition is based on a prior connection over which we have no control. Even if we could learn to develop some control over the beating of our hearts, this would have to be based on a prior natural connection between the thoughts of our mind and the actions of our bodies.

Conclusion

In Book 1 of his *Recherche* Malebranche stressed that our commerce with the external world around us is mediated not only by non-perspicuous sensations, but also by what he called 'natural judgments'. These judgments, involve a 'compound sensation' which, like simple sensations, represent external objects in such a way that they are useful for the preservation of our bodies.[81] One example he gives is of our judgment of size constancy: in spite of the decreasing size of my retinal image when a man walks away from me, 'I see him as always having the same size'. The decreasing size of the image of the man walking away from me is combined with the 'impression of distance' which is received simultaneously.[82] This latter impression, at least for objects which are fairly close, derives from the 'change that occurs in the state of our eyes according to the changes' as the angle, which is formed by drawing lines from each eye to the point of focus of the object, decreases in size.[83] However, Malebranche recognized that this angle is nothing of which we have any direct awareness. He denies that the soul has the knowledge to make such judgements, which require 'an infinite power and intelligence'. According to Malebranche, we lack the knowledge of 'that which actually occurs in our eyes and brain' which would allow us to make such natural judgments ourselves. Such judgments, he stresses, are made by God 'in us, independently of us, and even in spite of ourselves'.[84]

Like Malebranche, Perrault recognized that in order to survive in the world we must make natural judgments. In the fourth chapter of 'Du Bruit' he discusses 'the judgment that the animal employs to avoid errors, in which the senses . . . can fall'.[85] He notes that generally 'a confused and habitual judgment' is satisfactory for these purposes, and that we seldom need to make a judgment which is 'explicit and distinct'. He mentions in particular the various visual cues we use to see an object as being always the same size, in spite of the fact that the image on the retina grows bigger or smaller depending on the distance of the object from us. Like Malebranche, Perrault thinks this judgment is made habitually and unconsciously. However, for Perrault, unlike Malebranche, these judgments are made by the individual soul itself. Like Malebranche, Perrault insists that the natural judgments performed in a living body require knowledge, but for him the knowledge belongs to the individual organism, not to the Creator.

In general, the processes of an animal organism which Malebranche and Descartes ascribe to God or nature are ascribed by Perrault to the soul of the organism which animates it. In one sense Perrault is returning to the Aristotelian view of soul as the fundamental principle of life, rejected by Malebranche and Descartes. However, there is, as we have seen, an important difference: on Perrault's view the soul acts as an intelligent and free agent in performing the vital functions of the body. His soul is fundamentally different from the Aristotelian soul, in so far as, in all its operations, it possesses the intellectual and decision making powers of a mind or intellectual soul.

Notes

1 All references will be to the reprint of the *Essais de physique* in *Oeuvres diverses de physique et de mechanique de Mrs. C. & P. Perrault*, 2 vols. (Leyden, 1721).
2 But see Section 3. François Azouvi has shown that quite apart from his insistence on the need for a soul in the animal machine, the mechanism of animals is quite different for Perrault and Descartes. On this, as well as other themes developed in this paper, see his 'Entre Descartes et Leibniz: l'animisme dans les *Essais de Physique* de Claude Perrault, *Recherches sur le XVIIe siècle*, vol. 5 (1982), 9–19.
3 See Wolfgang Hermann, *The Theory of Claude Perrault* (London, 1973), 196. Azouvi, in the paper referred to in footnote 2, has shown many important parallels between the theories of the soul of Perrault and Leibniz.
4 There is an 'intellectual memory' mentioned in Descartes' letters after 1640 which does not depend on the body. However, it relates to the cognition of universals and does not dispense with the centrality of the body in memory of particulars. See the interesting discussion in Stephen Gaukroger, *Descartes, an intellectual biography* (Oxford, 1995), 392.
5 AT xi. 202. All translations are from Cottingham et al., *The Philosophical Writings of Descartes*, unless otherwise indicated.
6 *Discours*, AT vi. 46.
7 AT xi. 224–5.
8 Nicolas Malebranche, *The Search after Truth*, trans. Thomas Lennon and Paul Olscamp (Columbus, 1980), 495; *De la Recherche de la Vérité*, vols. I-III, ed. Geneviève Rodis-Lewis, third edition, *Oeuvres de Malebranche* (Paris, 1991) (henceforth, *Recherche*), ii. 394–5.
9 *Search after Truth*, 494: *Recherche* iii. 393.
10 Second set of Replies to the *Meditationes*: AT. vii. 160: 'Cogitationis *nomine complector illud omne quod sic in nobis est, ut ejus immediate conscii simis.*'
11 'I say "immediately" so as to exclude the consequences of thoughts; a voluntary movement, for example, originates in a thought but is not itself a thought.'
12 See Geneviève Rodis-Lewis, 'Le domaine propre de l'homme chez les Cartésiens', *Journal of the History of Philosophy* vol. 2 (1964), 157–88; Ferdinand Alquié, *Le Cartésianisme de Malebranche*, 167ff.; E. Brehier, 'Les "jugements naturels" chez Malebranche', in *Malebranche: recueil publiée par la Revue Philosophique* (1938); my *The Sceptical Realism of David Hume*, 221ff.
13 'Du Bruit' (1680) *Oeuvres Diverses*, i. 267.
14 Ibid., 269.
15 Ibid., 270.
16 Ibid., 267.
17 AT vi. 164.
18 *Principia* IV, art. 196, cf. IV art. 189.
19 AT xi. 176–7.
20 §§32 and 35.
21 *Dioptrique*, Discours IV, AT vi. 110–11.
22 AT xi. 141ff.
23 *Oeuvres Diverses*, i. 266.
24 Ibid., 267.
25 Ibid., 266.

26 '*Cet ébranlement étant aussi delicat qu'il est, il ne sçauroit se communiquer que par un corps homogene & transparent . . .; & tout nerf étant opaque, & par consequant composé de substances differentes, il ne m'est pas possible de comprendre que cet ébranlement ne finisse à la retine, & qu'il puisse passer au-delà.*' (ibid., 266).
27 *Dioptrique*, Discours IV, AT vi. 109.
28 *Oeuvres Diverses*, i. 267.
29 '*Il est certain que la maniere dont cet effet se produit, qui est que la privation du sentiment n'arrive point dans l'instant que la ligature est faite, & qu'elle augmente insensiblement en suite de la ligature, donne à connoitre que la ligature ne cause pointe l'insensibilité de la partie, en ôtant sa communication avec le cerveau.*' (ibid., 267).
30 *Principia*, IV art. 196.
31 However, for Perrault, unlike Descartes, the corrective judgement does not merely come from another sense. He writes that '*l'ébranlement des fibres fait à l'extrêmité du membre mutilé n'étant point tout-à-fait pareil à celui qui se faisoit autrefois dans les fibres de la main, il faudroit que le cerveau suppléât quelque chose que cet ébranlement des fibres du membre mutilé ne lui fournit point.*' (*Oeuvres Diverses* i. 288). This suggests that the brain should recognize a difference in the agitation which comes from the severed arm, which is precisely what Descartes thinks is impossible.
32 See especially section 3.
33 '*Je sçai bien, que ce qui oblige les Philosophes de supposer ce passage des images dans le fond du cerveau, est le besoin qu'ils ont crû que la memoire avoit d'un magazin, dans lequel les images fussent longs temps conservées.*' (*Oeuvres Diverses* i. 268).
34 '. . . *Quand cette impression, cette gravûre, & ce tracement de figures, qu'on suppose pour la formation de cette image, seroit concevable à l'égard de la vûe, qui consiste en effet dans l'impression que les objects font sur l'organe, où l'on peut s'imaginer qu'ils sont capables de laisser quelques vestiges d'une figure, parce qu'effectivement ils ont une figure, il n'en seroit pas de même de la sensation des objets des autres sens, qui comme tels n'ont aucune figure qui puisse former une image, si ce n'est par metaphore & par analogie. . . .*' (ibid., 268).
35 '. . . *Il n'est pas difficile de voir l'équivoque, par laquelle on prend ces deux manieres de conserver les images l'une pour l'autre, quoiqu'elles soient fort differentes, l'une étant corporelle & materielle, & l'autre ne l'étant pas.*' (ibid., 268).
36 *Search after Truth*, 106: *Recherche* i. 224.
37 *Oeuvres Diverses* i. 269.
38 *Oeuvres Diverses* i. 270.
39 '*On trouvera qu'elle ne peut pas aller de cette sorte; parce que les traces de l'image du chemin, qui auroient été imprimées dans le cerveau d'un cheval, quand il est venu, lesquelles seroient par example les images d'un chemin qui va du Couchant au Levant, & qui seroient propres, ainsi qu'on le suppose, pour disposer les jambes du cheval à se faire aller du Couchant au Levant, elles ne seroient pas propres pour faire remuer les jambes pour aller du Levant au Couchant; parce que ces lieux se présentant autrement aux yeux du cheval qui s'en retourne & d'une maniere opposée, sçavoir, du Levant au Couchant, seroient dans son cerveau des traces nouvelles, qui n'auroient aucun rapport avec les premieres. . . .*' (ibid., 270).
40 Ibid., 271.
41 Ibid., 271–3.
42 Ibid., 273.
43 Ibid., 329.
44 Ibid., 329.
45 *Oeuvres Diverses*, ii. 515.
46 Ibid., 517.
47 Ibid., 518.
48 Ibid., 514.

49 Ibid., 586.
50 *Oeuvres Diverses*, i. 278.
51 Ibid., 273.
52 Réponses aux quatrièmes objections, AT vii. 246.
53 *Oeuvres Diverses*, i 273, *et passim.*
54 *Oeuvres Diverses*, ii. 547.
55 *Oeuvres Diverses*, i 273, *et passim.*
56 *Oeuvres Diverses*, ii. 547.
57 Ibid., 548.
58 *Oeuvres Diverses,* i. 275.
59 *Oeuvres Diverses,* ii. 547.
60 *Oeuvres Diverses,* i. 278–9.
61 Perrault also comments (ibid., 277) that we demonstrate more rationality in the first months of our lives than we ever do subsequently!
62 *Oeuvres Diverses,* ii. 547.
63 *Oeuvres Diverses,* i. 279.
64 Ibid., 279.
65 Ibid., 274.
66 *Search after Truth*, 106, *Recherche* i. 223.
67 *Search after Truth*, 108, *Recherche* i. 226.
68 AT vi. 130.
69 AT viii. 81.
70 *Passions*, §34.
71 AT vii. 87.
72 AT vii. 88.
73 AT vii. 81.
74 It is interesting to note that Descartes himself considers and rejects this way of considering sensations early in the sixth Meditation. The seventeenth-century French translation approved by Descartes reads: '*Et parce que les idées que je recevois pars les sens étoient beaucoup* plus vives, plus expresses, et mesme à leur façon plus distinctes, *qu'aucunes de celles que je pouvois feindre de moy-mesme en méditant . . . il sembloit qu'elles ne pouvoient proceder de mon esprit.'* (my emphasis, AT ix. 60). In the *Principia* (I, arts. 45–6) Descartes appears to hold that sensations are normally 'clear' but *not* 'distinct' (AT xiB. 44).
75 *Oeuvres Diverses*, ii. 550.
76 '*Les unes & les autres sont employées dans les sensations, qui sont ou douloureuses ou agréables, le premier effet que objet produit étant d'exciter la pensée confuse de la maniere qu'il le fait ordinairement dans toutes les fonctions naturelles; mais parce que la dans les causes de la douleur ou du plaisir la solution de continuïté a quelque chose d'extraordinaire, la pensée confuse reveille la pensée expresse . . . et se trouve accompagnée de la reflexion par laquelle on sçait que l'on sent. . . .*' (Ibid., 550).
77 Ibid., 518.
78 Ibid., 518–19.
79 'Du Bruit', *Oeuvres Diverses*, i. 277.
80 §44, AT xi. 361.
81 The senses 'inform us of things only in relation to the preservation of our bodies and not as they are in themselves' (*Search after Truth*, 46; *Recherche* i. 119). Cf. Descartes: '. . . The proper purpose of the sensory perceptions given to me by nature is simply to inform the mind of what is beneficial or harmful for the composite of which the mind is a part . . .' (AT vii. 83).
82 *Search after Truth*, 34: *Recherche* i. 97.
83 *Search after Truth*, 41; *Recherche* i. 109.
84 *Search after Truth*, 46–7: *Recherche* i. 119.
85 *Oeuvres Diverses*, i. 284.

28 The body and the brain

John Sutton

1 Self-knowledge and the body

Does self-knowledge help? A rationalist, presumably, thinks that it does: both that self-knowledge is possible and that, if gained through appropriate channels, it is desirable. Descartes notoriously claimed that, with appropriate methods of enquiry, each of his readers could become an expert on herself or himself. As well as the direct, first-person knowledge of self to which we are led in the *Meditationes*, we can also seek knowledge of our own bodies, and of the union of our minds and our bodies: the latter forms of self-knowledge are inevitably imperfect, but are no less important in guiding our conduct in the search after truth.

If our textbooks acknowledge the connections Descartes sought to make between 'metaphysics, medicine, and morals', the three principal branches of the tree of knowledge,[1] they focus on his elimination of contingency. Just as, we are told, Descartes excludes from the mental realm anything which smacks of accident, fallibility, or uncertainty (let alone passion or mortality), so he thinks we can, partly through objective knowledge of the body with which the soul is temporarily united, learn to restrict the scope of our desires, accept what we cannot change, and thus live better.

According to this interpretation, the metaphysics of the free rational mind required the contrasting reduction of all bodies to sameness, to fit a single micromechanical model. In a curious consensus across analytic history of philosophy, medical anthropology, feminist theory, dynamicist cognitive science, and phenomenology, the assumption that Descartes stamped out context and particularity stretches into an image of Descartes as anti-magus, stripping nature and the body of all powers and activity. His objectification of the human body is, on this view, but one symptom of the mechanistic violation of an earlier enchanted world. Where once holistic herbalists and natural magicians embraced analogy and sympathy over representation and intervention, coupling earthy bodily realism with organicist ecologism, the Cartesian birth of modernity enforced divisions of philosophy from biology, science from history, power-mongering manipulators of nature from the dead ecology which they exploit, and of active rational male observers from passive fragmented female bodies. Despite a marvellous debunking by T.M. Brown of attempts to set up Descartes as villain in New Age psychosomatics and 'liberatory eco-holism', and despite powerful warnings about fetishised 'false nostalgia' for 'some lost, but recoverable, perfection' in the pre-Cartesian world,[2] this sad narrative of disenchantment retains its cultural force. Descartes, we are told, made the body just another object in a world 'not of meaning and love and laughter and tears . . . but of material particles going about their lonely business': and the person subsequently disappeared from medical theory, since this 'materialization' of flesh 'takes the juice out of animate bodies, leaving only bare bones and pulp'.[3]

From another direction, pragmatic critiques of the ideal of self-knowledge seek to undermine the very plausibility of finding truths about the self. Ian Hacking, for example, is sceptical about the idea, 'dazzling in its implausibility', that memory might provide a kind of 'scientific key to the soul' by uncovering 'facts' about what happened deep in personal history. From this point of view, the Cartesian confidence in the possibility of erasing the accidental effects of our specific education and experience, our bodily and psychophysiological quirkiness, as we embark on the Method, might be seen as a precursor of the characteristically modern error of basing a picture of *how* to live on some putative *facts* about inner sense.[4] And in Adam Phillips' diagnosis, the body is the first casualty of Descartes' perverse quest for certainty about the self: because of the body's entanglement in dependency and risk, the expert relies on the mind, 'a fiction invented to solve the problem of wanting to make the turbulence disappear'.[5] In theory as in life, difficult work is required to restore a sense of the erratic.

Some writers take a more positive view of Descartes' individualism, but still ascribe individuality only to Cartesian *minds*. Margaret Atherton, citing the encouragement which seventeenth-century women intellectuals like Mary Astell and Damaris Masham found in Descartes' concept of reason, emphasise a quite general notion of reasoning which is open equally to all. The only relevant differences are between humans and animals or machines, who do not reason at all: differences *between* humans, due to the idiosyncratic nature or history of individuals and their bodies, are less significant.[6]

A further, diverse group of philosophers who are engaged with quests for objective knowledge of self in contemporary 'dynamical' sciences of mind nevertheless share the negative appraisal of Descartes' efforts in this direction. They are united in opposition to 'a generally Cartesian picture of the nature of mind', by which cognitive processes are cut off from the world in 'a realm whose essence owes nothing to the accidents of body and surroundings'.[7] Even if cognitive scientists have successfully dropped dualism, we are typically told, they have retained Descartes' persistent, insidious explanatory divides: 'perception, thought, and action must be temporally distinct, and theoretically separable', while body and world are relegated to (respectively) a mere 'courier system' for sensory and motor messages to and from the thinking thing, and an alien source of input with which minds must sadly and indirectly interact.[8]

In this paper I reject the interpretation of Descartes, shared by many of these critics, which makes Descartes' dualist view of the body as negative or as pathological as that expressed by Socrates in Plato's *Phaedo*. I argue not just that the old moral cosmobiological disgust at the body is absent in Descartes, but that, positively, Descartes *requires* us to contract full intimacy with our own body and our own peculiar past. He does wish for objective knowledge in these difficult domains, but this does not render his neurological ethics a universal prescription, for such objective knowledge is nevertheless knowledge of local phenomena, of the peculiarities of idiosyncratic associations. Civilising the body, in seeking dominion over it, is a *process*; and, I will argue, Descartes was too firmly convinced that the body constantly changes its nature to have thought consistently that the process could come to an end.

I start with attention to the points in Descartes' work at which difference, dynamics, and the erratic take centre stage, to sketch a more ambitious and more speculative interpretation of possible relations between human nature, medicine, and morals. Descartes told Burman that he did not like writing on ethics.[9] He rejected the notion that philosophy should seek to regulate the behaviour of others: that, he wrote, is the business of kings and other authorities.[10] The goal of his reductionism is a form of care of the self based on knowledge of one's own body and one's own history. When Adam Phillips worries over the ease with which even an apparently disruptive framework like Freudian psychoanalysis can become 'a covert continuation of the Cartesian project', as scientistic optimism seeks to know and subsume the dynamic unconscious, he sketches a shadow, 'anti-Enlightenment' Freud whose aim is not self-knowledge, but tolerance of the impossibility of self-knowledge. I borrow Phillips' strategy, identifying glimpses of a shadow Descartes who also remembers that not everything can be remembered or accounted for, not every circumstance circumscribed. For Descartes as for Freud, the sources of this preference for care over expertise lie in a set of views on the dynamics of the mind–body union.

My case rests first on an analysis, in the next three sections, of capacities which, according to Descartes, we share with other animals. Sections 2 and 3 argue for strongly dynamic interpretations of Descartes' views on body and on corporeal memory respectively. Then Section 4 backtracks to support more firmly the surprisingly complex form of 'automatic' responses which I attribute to Descartes' beast- and body-machines. Finally, in section 5, I reintroduce the soul and the capacities for reflection which it allows in the human compound, showing how closely

Descartes thinks we must work with the body, its habits and its history, in deliberately moulding our associative responses with active mind.[11]

Immersion in Descartes' physiology and general natural philosophy shows how deeply Descartes cares about the vast range of human capacities which involve change in time. In the face of this bewildering range of critical attacks, the rehabilitation of the evil demon of modern philosophy of mind is of more than scholarly interest. These critics do often explicitly distance the Descartes whom they are merely 'invoking . . . as an emblem' from the more complex views of the historical Descartes.[12] But a cramped and implausible vision of 'modernity' too easily results: it is not just *historically* crude to characterise modernity by announcing that 'from Descartes' time on, attention was focused on timeless principles that hold good at all times equally: *the permanent was in, the transitory was out*'.[13] If we care about both self-knowledge and contingency, remembering that brains, for example, are both complex and particular, and that there can still be sciences of mind without the goals of control and total predictability, we might wonder if, paradoxically, Descartes himself could hint at the possibilities and the perils of what's become known as 'post-Cartesian agency'.[14]

2 Bodies

Knowledge of the brain and body, Descartes claims, can help in two ways. The understanding of human and other organic bodies which I acquire in studying physiology aids the general quest for assured rules in medicine and for the blessings of health.[15] But the physiological framework itself demands, second, attention to *specific* bodies: the body I will come to know best is not anonymous but particular. As natural philosopher I may seek to master *my* body as well as 'body' in general, but it escapes my will to dominate it because its boundaries are not firm, and because it is constantly changing. I may, and indeed should, seek in turn to *possess* my body, to make it more securely my own, but all that this amounts to is interminable attention to the shifting effects of its internal patterns, the true causes of which may always escape my notice.

In extending mechanism to the biological domain, Descartes stresses the potential complexity of mechanical phenomena. The earthen machines described in *L'Homme* are importantly unlike the clocks and simple automata with which they are conceptually analogous, for their capacities far outstrip those we usually imagine or ascribe to them.[16] Human and animal bodies are neither passive nor predictable, for, as one historian of physiology puts it, Descartes was 'a representative of the baroque, partial to a dynamic conception of nature'.[17] But can this be so? Is it not the defining feature of the mechanists' programme that nature should be drained of all activity, the organism being submerged by the machine?[18] And even if Descartes failed to eliminate all dynamism from his picture of the body, won't this just leave him with an oddly Rococo physiology within a general physics of barren matter?

Nature

Certainly Descartes, like Mersenne, sought sharp contrasts between nature and the active supernatural realm. But this is achieved through a minimal requirement that matter be inert, which comes to little more than the point that changes in motion must be due to the contact action of matter on matter, rather than to any ultimately intrinsic tendencies. Reminders that forces must *ultimately* derive from God in no way push those forces outside matter as we find it in natural philosophy: Descartes thinks it 'certain' that, once a body has begun to move, it 'has in itself for that reason alone the power to continue to move'.[19] Since 'there is nothing anywhere that is not changing',[20] and since 'there are infinitely many diverse motions that endure perpetually in the world',[21] all bodies in nature always have power within themselves.[22]

Descartes bases his accounts of these motions on his understanding of the dynamics of fluids. In cosmology, solid bodies like planets, which are packed conglomerations of corpuscles, are 'embedded in a fluid which carries them along in a vortical motion'.[23] This physics of circulation, displacement, and endless motion is secured by rejecting the void in favour of a plenum.[24] Moving bodies are always surrounded by other bodies, which move as they move. There is no fluid-free part of the plenum, so bodies are always in mutual causal contact, with every natural interaction being part of a continuous field of interconnected interactions.

This means that the ideal fiction of atomist kinematics, the attempt to break down complex interactions into sets of isolated collisions in the void, is never a realistic goal in Descartes' corpuscularian hydrostatics. Descartes does not start by thinking of bodies moving entirely without constraint, free of surrounding context; instead, he proceeds by assuming that 'systems of constraint are constitutive' of the phenomena under investigation.[25] The full fluid cosmos, then, is causally holistic, with every context-dependent motion inevitably coupled with other motions.

This holistic mechanism cannot entail deadening inattention to emergent phenomena, to the ways in which wholes act differently from their parts. The physics is indeed reductionist, in the sense that all events are constituted by microscopic impacts and collisions, but this in no way entails that understanding of vortical or other complex motions can be achieved without attention to local and temporal patterns of change in their particular physical contexts. Correspondingly, mechanism did not require the *elimination* of puzzling and complex natural phenomena. Indeed, Descartes accepts some of the stranger facts of the organicist world: he rejects not the baffling phenomena (the bleeding of wounds on the approach of the murderer, the weapon salve, sympathies, the maternal imagination imprinting on the foetus), but only certain candidate explanations of these phenomena which attribute thought or free will to corpuscles.[26]

Human bodies

But this is not yet a dynamic *physiology*. Even if Descartes' physics is modelled more closely on the mechanics of fluids, does he not still close off the human body, rendering it a possession of the individual soul? Drew Leder clearly articulates the view that a Cartesian devitalising and demystification of the body worked to neutralise and subdue any corporeal threat, so that bodily events, including death, happen as if to another: 'the true self cannot be threatened by the demise of that which from the start was mere mechanism.'[27] The triumph of 'the colder eye of science', it seems, silenced the human body, which was 'divested of its latent capriciousness'.[28]

But it is not true that in Descartes' work 'all spirits were effectively removed from nature',[29] as Catherine Wilson argues, 'there is no sudden impoverishment' in corpuscularian natural philosophy.[30] The survival of troublesome 'animal spirits' at the very core of Descartes' physiological theories is not an accidental residue, a pun uneasily transmitted between organicist and mechanical worlds. Descartes thinks of them primarily not, in the howler to which students are commonly directed, as the intermediates which 'solve' the mysteries of mind–body interaction, but as the impetuous nervous fluids which drive the brains of animate machines. Animal spirits (which are neither animals nor spirits) 'are merely bodies'.[31] The finest, most subtle, fastest-moving parts of the blood, these spirits 'vary in strength depending on the differences in the particles which make them up'.[32]

It is customary to see the partial survival of ancient and Renaissance physiologies of humours and spirits in Descartes, if acknowledged at all,[33] as a mark of his failure, of the extent to which the exuberant, radical ambition of his mechanism was bound to need illegitimate supplementing, in explanatory practice, from tradition and lived experience. In developing what Emily Grosholz labels a 'corpuscularized Galenism',[34] Descartes, on this view, tacitly introduces old dynamically tinged annexations which enrich and thus violate a basically pure, static official mechanism.

But the survival of non-linear feedback systems in physiology at which Grosholz bridles looks quite different if we do not assume in advance that mechanism and dynamics must be incompatible. The incorporation of spirits into pulsing body-machines was part of an adaptation, not a wholesale rejection, of older medical holisms. Bodies are still porous, spongy, thrown, fragile.

In the mixed Hippocratic/Galenic traditions (tied only loosely to specific ancient texts) which fuelled learned Renaissance medicine, the state of animal spirits, blood, and other 'naturals' varied with the changing influences of the 'non-naturals': climate, food and drink, sleep, motion, evacuation and repletion, and the passions worked on the spirits either through the blood or directly through the skin.[35] Highly individualised schemes of therapy required attention to regimen, diet, sexual behaviour, travel, and responses to stress and distress.[36] In continual interaction with the *krasis* (blend) of internal fluids, the non-naturals combined to produce an individual's current, fragile balance against imminent stagnation or excess. Only those who denied animal spirits and their influence by airs and places, like William Harvey, would 'cut man off from his environment'.[37]

The individual's specific fluid balance depended on more than initial biological temperament (by which some were predisposed, for example, to melancholy and domination by Saturn), for this temperament *was* just the dynamic mixture of fluids in different proportions and conditions. So theories of individual *complexio* were at once medical and cultural.[38] The departure of internal mixture from its (relative, changing) 'proper blend' due to excessive, deviant, or insufficient environmental or psychological input was a framework for explaining not only disease but also the varieties of health.[39]

These psychophysiological frameworks were dynamic in that they assumed what modern dynamicists call 'continuous reciprocal causation', a mesh of 'mutually modulatory influences linking brain, body, and world'.[40] The dynamicism implied in physiological theory was also, as Gail Paster argues, part of lived experience: bodies were (not only theorised as but lived as) semipermeable irrigated containers, moist sponges filled with interchangeable fluids.[41]

Descartes does not deny or neutralise this framework. He accepts the turbulence of the innards and the continual exchange between world and body as key physiological *explananda*. The animal spirits connect the deepest interior, the pineal gland, with the world, for their condition shifts with changes in environment, climate, diet, and habits, and with changes in other parts of the body.

In *L'Homme*, after extended treatment of the senses,[42] Descartes turns to the 'internal senses'. His careful approach to the internal senses has recently been given some weight,[43] and it is clear that he breaks with tradition by including hunger and thirst in his list of internal senses.[44] But what is striking about the structure of *L'Homme* is that, while Descartes does then go on to discuss imagination, memory, and dreams (topics which his readers would have expected to find under the label of internal senses), he feels it necessary first to expand greatly on his earlier account of animal spirits.[45] As well as suggesting some specific causes of emotional states in the variations of animal spirits (see section 3 below), Descartes undertakes in turn to explain the causes of these variations: spirits can differ in quantity, in the coarseness of their constituent particles, in their degree of agitation, and in the uniformity or diversity of their size, shape, and force.[46]

It is hard, I suggest, to overestimate the pivotal role which these differences in the nature and flow of animal spirits play in Descartes' picture of brain and body. The differences derive in part from changes in the nature of the blood from which the particles which compose animal spirits are filtered or separated.[47] Descartes devotes a lengthy passage to explaining that 'whatever can cause any change in the blood can also cause change in the spirits'.[48] These factors include a wide array of internal and external influences. The qualities of food and the nature of the rhythmic digestive processes, the nature of air inhaled and mixed with blood in respiration, and the disposition of the liver which elaborates blood going to the heart all affect the abundance and degree of agitation of the spirits produced by that blood;[49] gall bladder and spleen must remove, respectively, parts of the flammable and of the inflammable components of the blood before it reaches the heart; and 'the little nerve that ends in the heart' modulates the flow of blood into and out of the heart, so that it 'can cause a thousand differences in the nature of the spirits'.[50]

The continuous influence of all these factors on blood and thus on animal spirits connects or couples the human body, 'with its interactive openness',[51] with the physical and social world. Descartes has broken from the cosmobiological tradition which identified bodily spirits with quintessential cosmic spirit; but this identity had never been ubiquitous among spirits theorists, and certainly was not required to force attention to the dangers and difficulties of the ceaseless exchange of fluids between body and world.[52] Malebranche, introducing his account of the passions, draws on this physiological holism in arguing against the Stoic view that our happiness depends only on ourselves. We are joined, as a result of sin, by our body 'to all sensible things', and it is God's will that all created beings 'should depend on one another'. After the Fall,

> we are to some extent joined to the entire universe. . . . There is now no one who is not both joined and subjugated to his body and through his body to his relatives, friends, city, prince, country, clothes, house, land, horse, dog, to this entire earth, the sun, the stars, to all the heavens.[53]

It is hard to get more holistic than that. This is a field of multiple simultaneous interactions in which everything simultaneously affects everything else. Changing external parameters like diet, climate, social interaction, and stress, which change at a relatively slow rate, directly affect the fast dynamics of internal state variables of blood and spirits: but because the spirits partly cause behaviour, changes in those external parameters are themselves partly caused by the internal processes with which they are coupled.[54]

The body and the brain

Now we can apply this biophysics to the brain. Animal spirits, once separated from the blood, pass from the pineal gland through the cerebral ventricles and into the brain. There they flow through brain pores, to which Descartes assigns a central explanatory role. Pores are like 'the spaces that occur between the threads of some tissue; because, in effect, the whole brain is nothing but a tissue constituted in a particular way'.[55] The brain is a net or mesh of filaments with pores between them. The pores are affected by the motions of animal spirits in three ways. Pores can be 'diversely enlarged or constricted by the force of the spirits that enter them', and, second, the filaments 'can be flexed rather easily'. Most important here, the filaments 'can retain, as if made of lead or wax, the flexure last received until something exerts a contrary pressure upon them'.[56]

The harmonious functioning of the body depends on the spirits, the pores, and the distribution of spirits through the pores.[57] This distribution of spirits is unceasing, since the spirits are in continual motion.[58] Flowing into the brain from the cavities, they trace figures by their motions through the pores. Descartes uses both 'trace' and 'figure' for these explicit, transient patterns of motions at a time. The spirits in the neural system keep the filaments 'so tense' that figures are easily transmitted.[59]

There are two distinct kinds of 'trace' or 'figure' in play in Descartes' account of brain processes. There are transient patterns of spirit motions. But there is also the pattern of filaments and pores, an architecture of connections which is itself modifiable but which does endure longer than the motions.[60] These are the flexures which, Descartes suggested, can be retained over time.

As well as this distribution of spirits through the cavities and pores of the brain, the spirits figure in a less direct relation or balance between the brain and the body. Not all particles of blood are fine and lively enough to pass up through the carotid artery to the brain and become animal spirits; others are drawn instead to 'the organs designed for generation'.[61] As Desmond Clarke shows, a specific hypothesis of a link between intellectual activity and male fertility, based on the 'dependence and communication which obtains between the spirits of the brain and those of the testicles', quickly became entrenched in Cartesian physiology, so that 'those who weary their imaginations by study are less suitable for procreation, while those who, on the contrary, dissipate their minds in debauching women are not as suitable for study'.[62] While in *L'Homme* Descartes himself did 'not wish to enter further into this matter', I will suggest below that he did take related problems about control of the distribution of spirits to have a significant moral force.

3 Memory

One key problem in physiology which animal spirits had long been used to answer was muscular motion. Many, like Descartes, thought that spirits flow from the nerve into the muscle in contraction.[63] This balloon or inflation theory of muscular motion would become increasingly important in debates about the existence of animal spirits from the 1660s onwards.[64] But the influence of animal spirits was not restricted to straightforwardly physiological topics: spirits were requisite theoretical entities in Renaissance accounts of memory, dreaming, and imagination, and of emotion, moods, and madness.

Descartes knew how thoroughly Renaissance psychologists, in what Burton called 'those tedious tracts *De Anima*',[65] employed animal spirits to embed cognitive function in the body. He followed tradition in extending the scope of spirits theory from the physiological to the emotional. Differences in the abundance, coarseness, agitation and uniformity of the particles of spirits alter our humours or 'natural inclinations'. Unusual abundance excites movements that give evidence of generosity, liberality or love; coarseness or strength of the spirits gives rise to confidence or courage, agitation to promptness, diligence and desire, and so on.[66] In the *Passions*, these physiological-fantastical accounts of the peculiarities of spirit motions are further developed: in hatred, for example, gall entering the blood from the liver boils up and causes spirits going to the brain to 'have very unequal parts' and to 'move very strangely'.[67]

So the thoughtless zombies of *L'Homme*, who can imitate all human actions, are not restricted to capacities we take to be physiologically basic. They can not only move, breathe, sleep and wake, nourish themselves, digest, and reproduce; they also have what are to us mental capacities like sensation, memory, imagination, and emotion. Even commentators who prefer a much more austere interpretation of 'Cartesian mechanism' than that which I am advocating agree that Descartes' description 'models activity which looks very much like cognition'.[68]

Figures transmitted by or in the incessant motions of animal spirits are 'imprinted in the internal part of the brain, which is the seat of Memory'.[69] This is achieved through bending or rearranging brain filaments so as to alter the intervals between pores through which the spirits will flow in future. The spirits 'trace figures in these gaps, which correspond to those of the objects'; on the repetition of a pattern of input, more enduring changes are made in the pores, so that figures can be more easily formed again, in the absence of the specific stimulus.[70] The pattern of the pores, which constrains the patterned flow of spirits, is itself altered over time by the differing motions of the spirits. These patterned motions are not themselves stored, but merely 'retained in such a way that' previous figures can be recreated. Even if a particular input is only partially re-presented, recognition may still occur if the connected pores have been disposed so as to open together more easily.[71]

So as Hall notes, for Descartes, 'memory traces . . . consist in residual patterns of openness among the interstices of the filamentous brain substance'.[72] Only physical factors need be involved in reconstruction: the soul may play a part, when united to the machine, but it is not necessary for memory operation. It 'usually happens', according to Descartes, that 'several different figures are traced in [the] same region of the brain'; thus, 'the spirits will acquire a [combined] impression of them all'.[73] So memories are motions, rather than separate atomic items, and representation in memory does not operate by resemblance. Every trace in a brain region affects any episode of processing; so every memory is composite, just as every sensation dangerously carries the perceptual history of the perceiver. This is how 'chimeras and hypogryphs are formed in the imaginations of those who daydream', who neglect the twin direction offered by external objects and by reason.[74] Descartes was aware that his account allows this kind of misassociation, or the intrusion of imagination into memory. This was the subject of the most intense criticism of his views: Joseph Glanvill, in one of a number of powerful English attacks on theories of corporeal memory as motion, complained that on such a view,

> one motion would cross and destroy another; all would be clashing and discord . . . our memories will be stored with infinite variety of divers, yea contrary motions, which must needs interfere, thwart, and obstruct one another: and there would be nothing within us, but ataxy and disorder.[75]

Despite such worries about the confusing effects of interference, this form of storage does avoid the problem of finding room in the brain for every memory, which had worried Descartes in the *Regulae*.[76] In 1640, Descartes tells Mersenne that there need not be a very large number of 'folds' in the brain 'to supply all the things we remember', because a single fold can 'store' many related traces;[77] in other words, experience (in the form of motions of the animal spirits) moulds the patterns of filaments and pores in such a way that old motions can be reconstructed more easily.[78] Malebranche, developing Descartes' account, would simply dismiss 'the prejudice that our brain is much too small to be able to preserve such large numbers of traces and impressions' on the grounds that memories are only 'the changes occurring in the fibres' of the brain.[79]

Note that nothing in this account violates Descartes' dualism, requiring us to interpret him as a closet materialist. It may be surprising that belief in a non-physical mind could coexist with a neurological approach to memory, or that Descartes elaborates such microbiomechanical detail when he sees human flexibility in linguistic response and rational action as forever beyond the powers of matter. But, for him, corporeal memory is not a mental capacity at all, where this means that it does not require consciousness or soul. Its explanation is embedded among other life functions; although there can be no Cartesian science of the self-conscious mind, there can and must be sciences of memory, imagination, dreaming, and so on.

But if this whole spirits-and-traces fantasy refers only to *implicit* memory, memory where there is no conscious reference to the past, is corporeal memory really a true kind of memory at all? Implicit memory, understood merely as the non-conscious effects of past experience on ongoing brain processing, may be important for biological success, but is it not a far cry from the explicit, subjective autobiographical remembering characteristic of beings like us?

The first response to this objection is to note that Descartes definitely does see corporeal memory as a genuine kind of memory, albeit one not unique to humans: he stresses that it is the most notable effect of memory that 'without there being any soul present in this machine, it can naturally be disposed to imitate all the movements' of true humans.[80] So Descartes is not confused in attributing memory to animals:[81] as he tells Elizabeth, impressions can be formed in animal brains by, among other things, 'the traces of previous impressions left in the memory, or by the agitation of the spirits which come from the heart'.[82]

My point here is not merely to support the increasing consensus that the 'beast-machine' doctrine still allows sentience, memory, and imagination to animals:[83] rather it is to stress just how Descartes thinks that the soul, when it *does* play a causal role, must build on and use precisely these associative mechanisms among spirits and brain pores. He continues his point in the letter to Elizabeth by arguing that 'in man the brain is also acted on by the soul, which has some power to change cerebral impressions'. I will suggest in the final section of this paper just how literally Descartes takes the moral importance of this power of the soul. But I must first provide a more thorough response to the objection I just canvassed. Surely, without a soul, the only kind of 'memory' possible would be reflex action, mere automatism? Is not the fact that Descartes' physiology of memory excludes consciousness not enough for us to dismiss it, as it seems 'clear that the one thing Descartes was not explaining was the *psychologicality*' of memory?[84]

4 Automata

Put this way, the objection to my reading of Descartes on corporeal memory trades on a dichotomy between two kinds of response to the world. One form of response is inflexible, wholly stimulus-driven, while the other is incorporeally mediated conscious action. The first form covers all animal behaviour and much human behaviour, and the second characterises true human action. I argue in response that this is not an exhaustive classification, and that Descartes accepts an intermediate form of interaction with the environment, including a wide class of responses of great interest to him and to us.

Owen Flanagan describes the impoverished world of the 'Cartesian automaton', restricted, because it is only body, to automatic reflex behaviour:

> the complete system of wired-in reflex arcs exhausts its behavioural potential. What a particular automaton does, how it in fact behaves, is the inevitable result of the interaction between the environment and the wired-in arcs.[85]

The point of Descartes' fables of automata, on this view, is to exclude the contingencies of individual experience from consideration in natural philosophy, for these automata are 'endlessly repeatable, and by definition not particular, not the subjects of a specific history'.[86] It is the consequent intelligibility of automata that is 'the fundamental point of Descartes' mechanical philosophy'.[87]

But there is no reason to accept that hard-wiring or biology, on the one hand, and current stimuli, on the other, must be the sole determinants of machine behaviour. The example of memory makes this easy to see. In the memory processes of the automaton, the effects of experience are transmitted over long temporal gaps, and are causally involved in behaviour mediated by complex internal processes. The determinism involved is not a simple stimulus/response link, for the corporeal causes act holistically. To put it another way, memory shows that an automaton's physiology changes over time. Automata with different histories, different 'experiences' marking their brains and bodies, will (*contra* Flanagan) respond differently, and one automaton will respond differently to the same stimulus at different times, after new experience has modified the pores and folds of its brain.

There are, of course, cases in which biology and environment are jointly sufficient causes of behaviour. Descartes' account of reflex phenomena is 'short on detail about the specifics of neuroplumbing',[88] but it seems clear that swallowing, blinking, coughing, sneezing, and yawning depend only on fixed, hard-wired arcs.[89] This kind of automatic behaviour is like the immediate, fixed chain between the passage of air through organ pipes and the particular sounds the organ produces.[90] Let us call this simple automatism. Here the pineal gland is not involved; the switch from sensory to motor response occurs when the entrance to a brain pore or tube is opened by the motion of a nerve fibre, and animal spirits from the ventricles enter and are carried through the nerve tubes to various muscles.[91]

Simple automatism is thus significantly different from processes like corporeal memory, which we might call a case of complex automatism. Memory requires ideas to have been traced in spirits on the surface of the gland, and to have been transmitted as figures to the modifiable pores of the brain, which incur enduring changes as a result. Reflex pathways are unalterable, whereas the folds of the brain which carry memory exhibit considerable plasticity. Simple automatism involves, we might say, no representation, as there is no need for the capacity for response to be extended over time. Remembering, on the other hand, is not simply automatic, even though it need not involve the soul.

There is extra evidence for this distinction between different classes of response available to Descartes' automata in his attitude to explanation by reflex. There are hard-wired immediate unconditioned reflexes in humans and animals: sheep run from wolves, and humans throw out their arms when falling 'without the assistance of any soul'.[92] But there are also much longer-term, yet still wholly physical, responses in which corporeal memory is at work. Some are cases we would call 'conditioned response', the acquisition of learned associations where there is no natural 'relation' between a representation and its 'meaning'. 'If you whipped a dog five or six times to the sound of a violin, it would begin to howl and run away as soon as it heard that music again.'[93] Setters can be trained, against their natural inclinations, to stop at the sight of a partridge and run towards it on hearing a gun.[94]

However, rather than conceptually isolating these conditioned responses in dog-machines, or linking them with simple reflex automatism (as Flanagan's picture would lead us to expect), Descartes couples them with more complex human cases which he considers equivalent in principle. The case of the dog howling at the music of whipping comes in the context of a discussion of individual differences in judgements of beauty: judgements often differ, Descartes argues, because of traces left by individual history. Music which makes one man want to dance may make another want to cry, because different ideas are evoked in memory: if the latter man has 'never heard a galliard without some affliction befalling him, he would certainly grow sad when he heard it again'.[95]

So not everything, in dogs any more than in humans, is innately wired in, for the movements of the brain change in the course of experience. Cartesian automata are not the uncanny 'Neurospasts', nimble sprightly puppets which only seem to be moved from within, feared by vehement English defenders of free will like Cudworth and More.[96] Once set in motion, they really are moved by changing internal states; they lack only the acausal autonomy attributed by Descartes to souls which will and act freely, and judge rationally. The long-term workings of corporeal associative memory are extremely flexible, and the notions of experience and individual learning history do apply. The diverse causal factors involved in registering, integrating, and acting on information include 'previous brain episodes' and non-neural bodily events, as well as current environmental input: 'this is the model of an automaton, to be sure, but not one which operates by reflex'.[97]

The natural philosopher's desire to master and possess nature, then, is inevitably limited by the complexity and the flexibility of the bodies with which the soul is united. It is just because body-machines are weak and exist in history, because hair turns white,[98] that medicine is central to Descartes' project. The myth of the pre-programmed machine dully reproducing its hard-wired fate, eternally churning out fixed action patterns, does not apply to the animated statues of organic nature. The intermediate level of response, neither simple reflex nor incorporeally derived action, opens up Cartesian bodies to memory and history, with all the sadness, resistance, and complexity which the matter of the past brings.

5 Passions

This plasticity of response in the machines with which souls are united is the basis for the neurological strand of morality. We need knowledge of our own internal processes as much because of the hopes and opportunities they afford us as because of the dangers with which they threaten us. But where Toulmin, for example, suggests that this is a recipe for 'moral escapism' by dividing us from our body, that Descartes' ethics 'relieves us of all responsibility' for the passions by treating them 'as mere effects of causal processes [and taking] them out of our hands',[99] I argue that Descartes urges the awesomely difficult moral task of excavating, managing, and correcting a vast and changing array of psychophysiological associations. Moral life is not the imposition of norms onto bodies from outside the causal field, but the slow, reciprocal adjustment of internal causes.

The organic automata of *L'Homme* function without a soul. But, unlike them, we do have souls; in the fabular context, Descartes tells us that 'God will later join a rational soul to this machine'.[100] What difference, then, will the soul make to this marvellously intricate engine? It may, first, make significant qualitative differences: animals, Descartes retorts to Fromondus, 'do not see as we do when we are aware that we see, but only as we do when our minds are elsewhere'.[101] But however this notoriously difficult view is to be understood, I suggest that Descartes also allows the soul to make something more like a quantitative or additive difference, providing us in the mind–body union with extra capacities which build on and employ those we have considered as bodies alone.

Using familiar material from the *Passions*, I hope to show just how far removed these processes of the union are from the bewildering kind of 'bifurcation' of inner and outer lives of which Ryle accused Descartes.[102] Some of the ways by which souls act on bodies are nothing at all like the direct and unicausal para-mechanical interventions of a ghostly governor; instead, they extend or apply the multicausal treatments of disease characteristic of 'pre-modern' medicine to the psychophysiological realm. The soul's occasional influence on the bodily states of associative memory is its only, imperfect way of instituting better habits in the wayward dynamics of spirits and brain.[103] Descartes does indeed acknowledge the kind of gaps between self and body which cosier Wittgensteinian and phenomenological philosophies repudiate; theory provides stratagems for identifying, coming to terms with, and occasionally healing these troublesome traces and 'wounds received by the brain'.[104]

At the end of the *Passions*, Descartes says that he has described two quite different classes of 'remedy' for the passions. One he calls the 'most general' remedy, as it can be employed when the other fails: when tempted by a passion or action which the intellect repudiates, we should call up other, opposing thoughts at will, seek to postpone action if appropriate, or simply distract ourselves with different thoughts. This strategy is 'readily applicable', Descartes says, and is the only remedy most people ever use.[105]

But the advice on life embodied in most of the book, and in many of Descartes' recommendations to Princess Elizabeth, is based on the other, much more difficult remedy, through which we can find wisdom and joy: those who are most moved by the passions, who have sufficiently prepared themselves by this method, 'are capable of enjoying the sweetest pleasures of this life'.[106] This second remedy requires, says Descartes, 'forethought and diligence', and long training. It is based on a single psychophysical principle, aptly dubbed the Principle of Habituation by Stephen Voss.[107] Descartes calls it 'the principle which underlies everything I have written about [the passions]'.

According to this associative principle, particular physical movements in the brain and body are joined with thoughts and passions. These linkages depend on 'nature or habit',[108] and they can occur between thoughts, on the one hand, and both overt bodily movements and internal motions of the brain and innards, on the other. They are of various different kinds and strengths. I want to work briefly through the varieties of connection, and in doing so to demonstrate how thoroughly this principle, introduced immediately after a reprise of Descartes' associative account of memory,[109] is integrated with that account.

The causes of these connections between bodily motions and thoughts or passions are all opaque to us as acting and thinking subjects: the correlations were set up either before our awareness, or beyond and beneath it. Any modifications we seek to make to psychophysiological responses must be just as indirect as our knowledge of them. As the will does not have the power to excite or displace the passions directly,[110] it is constrained to employ '*industrie*': this is 'artifice' or, we might say, (psychological) work in which knowledge of our nature and, most importantly, of our own history and experience, is laboriously brought to bear on the landscape of our pores and passions.

There are, first, fixed connections. Some movements of the brain cause passions by 'institutions of nature', instituted by God. These are generally to our benefit, for the preservation of life. They are parallel to the unconditioned reflex phenomena described above, but also include, for example, the emotional extensions of basic attraction and repulsion, such as sexual desire and the fear of death. When they become further associated with specific stimuli, these responses may be alterable; Descartes does not think that 'the touch of an earthworm, the sound of a rustling leaf, or our shadow' must forever bring dread because of our aversion to the threat of death they seem to bring:[111] indeed, eradication of the fear of death is, he tells Mersenne, 'one of the main points in [his] own ethical code'.[112] The precise sense in which they are 'fixed', then, is only that their institution depends simply on God and on the given nature of the machine, not on any historical or individual experiences.

The power of these 'biological' or natural connections is sometimes seen as the main threat to the good life. On this understanding of Cartesian ethics, Descartes 'offers the hope that by careful training, and the resolute exercise of our will, we can become not the slaves but the masters of our biological inheritance'.[113] This gives the impression that Descartes took the enemy, in moral life, to be the fixity of biology, the rigidity of the machine's programming, which it is the task of the will to overcome. It might seem that the conclusion to the *Passions* confirms this interpretation, as Descartes says that he has told us how to 'correct our natural faults'.[114] But the institutions of nature do not reach all that deeply: by themselves they are neither the main problem, nor the major hope. The 'natural faults' in question are not, I submit, this limited class of fixed connections between brain movements and specific passions, but rather the (fixed) mechanisms which, in contrast, support or ground variable connections, which are in fact Descartes' main concern. Not fixity, but our fixed tendency towards uncontrolled plasticity, is the problem.

So not nature, but what Descartes calls 'habit' (*habitude*) is the moral key. The term covers various kinds of *variable connections* between motions and thoughts or passions. Habits are grounded in dispositions, which in turn are grounded in the arrangements of physical parts.[115] '*Habitude*' reaches much further beyond the individual than does the English 'habit'. All the teachings of childhood are sedimented in associations: the route by which culture intrudes into the soul is by way of the brain. Descartes thus has a physiological basis for worry about our prereflective views of the world. He does not hold the intellectualist view that everything implicit in our forms of life must be explicitly encoded in the brain. This would require the equally implausible separate rooting out and challenging of each and every belief.[116] Memories do not have to be stored independently or discretely to be causally active; there are no independent storage boxes which can be either full or empty, only the sets of folding pores in the net of the brain. Our bodies thus hold cultural forms of life not as quasi-theoretical axioms, but as nested sets of causal tendencies, realised differently in each brain. Descartes' psychophysiology makes the kind of total epistemological reevaluation, and wholesale destruction of false beliefs, which mainstream interpretations attribute to him, quite incoherent. We should reject these interpretations, and acknowledge instead that Descartes accepts the inevitability of working with our prereflective cognitive equilibrium, while seeking also to hone in on the more damaging of the inconsistencies and anomalies, accretions of the (social and individual) past, which we have internalised.

So in addition to the ways that culture has, since childhood, soaked through the pores of the brain, there are also more particular 'habits'. Striking examples of these psychophysiological accidents of experience are phenomena of single-trial learning. Some dispositions of the brain can be acquired by a single action and do not require long practice: it takes only one nasty surprise in a favourite food to produce a permanent abhorrence.[117] These are the most extreme cases of the kinds of individual differences in which Descartes was keenly interested. They offer a physiological basis for his remark to Elizabeth that 'each of us is a person distinct from others whose interests are accordingly in some way different from those of the rest of the world';[118] difference, or history, arises already in the body and is not due solely to the possession of a separate soul. There is nothing natural about the experiential coupling of affliction with the hearing of a galliard. The cases Descartes typically describes are, like this, instances of aversion, in which a peculiar response to the smell of a rose or to the presence of a cat is due to some earlier individual trauma: in line with his general acceptance of associations set up before birth, he notes that someone, for example, may have 'sympathetically felt the sensation of their mother who was shocked by cats while pregnant'.[119] This extends backwards in developmental time the stress on the dual sources, in nature and habit, of association: just as natural connections may have been instituted in the womb,[120] so there is no principled reason why the *'habitudes'* of the mother may not have influenced association.

It is in this context that such aversions may be imprinted on or in a subject's brain 'till the end of his life',[121] without the subject ever being aware of it. The clear acknowledgment of this kind of permanent opacity of the operation of association marks the limit to the possible deprogramming and reprogramming of the body-machine by the soul.[122] But, fortunately, sometimes modification is possible. The point of the difficult remedy described throughout the *Passions* is to teach how we can apply ourselves 'to separate within ourselves the movements of the blood and spirits from the thoughts to which they are usually joined'.[123] This is the context of the story to which I referred earlier about altering the associations in the brain of a setter towards gunshots and partridges; with a little *'industrie'* the movements of the brain can be changed in humans, just as trainers can change them in animals, and, in general, movements of the brain can by habituation (*habitude*) be separated from the passions to which they have previously been linked, and joined again with others.[124] This is a slightly different sense of *habitude*, referring now not to the (past) setting up of an association, nor to the association thus set up, but to the potential process of *intentional alteration* of the brain by the self.

Descartes tells Chanut of his own experience of this kind of indirect changing of the brain in a story often quoted as a model in this context:

> . . . when I was a child I loved a little girl of my own age who had a slight squint. The impression made by sight in my brain when I looked at her cross-eyes became so closely connected to the simultaneous impression which aroused in me the passion of love that for a long time afterwards when I saw persons with a squint I felt a special inclination to love them simply because they had that defect. At that time I did not know that was the reason for my love; and indeed as soon as I reflected on it and recognized that it was a defect, I was no longer affected by it.[125]

This makes Descartes' hopes about the efficacy of intentional changes to the brain, and of the resulting moral improvement, seem wildly ambitious: working through is not so much harder than remembering or repeating after all. Schouls sees the *Passions* as Descartes' most extreme expression and defence of 'total mastery and . . . full autonomy', where complete fulfilment of the rationalist programme is uniquely envisaged; Cottingham remarks on Descartes 'deep optimism' about the prospects for these investigations into the physiological genesis of passions.[126] Descartes does indeed announce, at the rhetorically charged finales of sections 1 and 3 of the *Passions*, that this method can lead even 'weak souls' to 'acquire a quite absolute dominion over all their passions if one employed enough skill (*industrie*) in training and guiding them',[127] and that the Principle of Habituation, sufficiently well employed, acts as preparation 'against all the contingencies of life'.[128]

Must we return, then, to the encompassing ratiocentrism I invoked at the beginning of the paper, by which total expertise on the self is to be put to work in proto-technological control of one's own body? What will prevent this headlong rush for mastery degenerating into a behaviouristic nightmare, in which those who employ the skill in training and guiding might be authorities rather than oneself? Even though only thoughts are directly in our power, does this psychophysiological scheme not render almost everything else about us ultimately accessible to the marauding soul?

But Descartes did know that the effects of the past, traumatic or simply unnoticed, are not so easily retraced and worked through. The point that some accidental associations from the personal past may remain forever unknown[129] is enough to challenge his 'relentless optimism about the power and autonomy of the will'.[130] The Cartesian soul is not, as Adam Phillips sees it, an enraged bureaucrat, furiously cataloguing unmanageable emotions, making sure everything is accounted for in a system without secrets.[131]

First, we can note that the story Descartes tells Chanut is not necessarily a genuine case of the intentional alteration of association. Descartes does say that he 'reflected' on the true historical cause of his associations, but the very fact that it was undone immediately suggests that this was more of an accidental discovery than the careful investigation of psychological history which, Descartes acknowledges, can be a long and uncertain process which few people achieve.[132]

We might, further, invoke Malebranche's much more pronounced sense of human limitation, pointing out that it arises from precisely Descartes' considerations about memory and association. Traces in memory are inevitably confused together, with the 'unruly' animal spirits often exhausting the will in its attempts to lead them into 'new and difficult channels'.[133] Malebranche repeatedly invokes the principle of habituation, noting that, in passion, many traces are stirred up by animal spirits 'swirling irregularly in their brain', and that the soul, which is 'continually constrained to have the thoughts tied to these traces', can become 'as it were, enslaved to them'.[134] The most determined attempts to impose some fixity or solidity on them may fail to render us 'impregnable': sometimes the 'motion of the spirits can be so violent that they occupy the soul's entire capacity'.[135] It is true that 'before the Fall, the soul could erase the brain's images' and 'instantaneously arrest the disturbance in the brain's fibres and the agitation of its spirits merely by considering its duty'.[136] The psychophysiological consequence of the Fall, then, is just the possible failure of the project of recolonising the body and the brain with the intellect.

Descartes' sense of sin is not so pronounced; yet, since so much of the picture of plasticity in brain and body which I have outlined dictates against the notion that our psychophysiological capacities are perfectible, there is at least some interpretive ground for refusing to take his high rationalist rhetoric of totalising self-correction too seriously. To take it at face value and then to convict Descartes of over-intellectualist moralising is at least equally troubling. In arguing that Descartes imagines an end to inquiry about the self, a final termination to the self-analysis, such interpretations trade on just the picture of a static, rigid body which, I have suggested, is entirely foreign to Descartes' physiology. For as long as the union of soul and body continues, the brain and its spirits churn and change away, shifting the grounds of the associative dispositions which it is the work of the soul to refigure.

Notes

1 *Principia*, preface. AT ix. 14.

2 T.M. Brown, 'Descartes, Dualism, and Psychosomatic Medicine', in W.F. Bynum, R. Porter, and M. Shepherd, eds., *The Anatomy of Madness* (London, 1985), i. 40–62; Timothy J. Reiss, 'Denying the body? Memory and the dilemmas of history in Descartes', *Journal of the History of Ideas* vol. 57 (1996), 587–607: 592–3.

3 Jonathan Ree, 'Subjectivity in the Twentieth Century', *New Literary History*

vol. 26 (1995), 205–17: 205–6; Maxine Sheets-Johnstone, 'The materialization of the body', in M. Sheets-Johnstone, ed., *Giving the Body its Due* (New York, 1992), 132–58: 134.

4 Ian Hacking, *Rewriting the Soul* (Princeton, 1995, 209), although Hacking does not deal with early accounts of self-knowledge, and would likely reject my historiographic analysis, since he believes that 'there was little conception of a knowledge about memory before the nineteenth century.' (219).

5 Adam Phillips, *Terrors and Experts* (Cambidge, MA, 1996), 93–104.

6 Margaret Atherton, 'Cartesian reason and gendered reason', in L.M. Antony and C. Witt, eds., *A Mind of One's Own* (Boulder, 1993), 19–34.

7 Timothy van Gelder, 'What could cognition be, if not computation?', *Journal of Philosophy* vol. 91 (1995), 345–81: 379; Andy Clark, *Being There: putting brain, body, and world together again* (Cambridge, MA, 1997), xi.

8 Michael Wheeler, 'Escaping the Cartesian mind-set: Heidegger and artificial life', in F. Moreno et al, eds., *Advances in Artificial Life* (Berlin, 1995), 65–76: 67.

9 AT v.178. For these quotations see also John Cottingham, 'Cartesian Ethics: reason and the passions', *Revue Internationale de Philosophie* vol. 195 (1996), 193–216: 196. My discussion of the passions is much indebted to Cottingham's.

10 Descartes to Chanut, 20 November 1647, AT v. 87.

11 The material on memory and automatism, in particular, is developed more fully in my *Philosophy and Memory Traces: Descartes to connectionism* (Cambridge, 1998), especially 55–81. Here I employ it in detailed discussion of the role of psychology in the quest for self-mastery.

12 Antonio Damasio, *Descartes' Error* (London, 1995), 247; compare Drew Leder, *The Absent Body* (Chicago, 1990), 198–9.

13 Stephen Toulmin, *Cosmopolis: the hidden agenda of modernity* (Chicago, 1990), 34 (original italics).

14 Van Gelder, 'What could cognition be . . .?', 379–81.

15 AT vi. 62.

16 AT xi. 120. On this point, compare Gordon Baker and Katherine Morris, *Descartes' Dualism* (London, 1996), 37.

17 Karl Rothschuh, *History of Physiology*, trans. G.B. Risse (Huntington, NY, 1973), 78.

18 Carolyn Merchant, *The Death of Nature: women, ecology, and the scientific revolution* (New York, 1980), 193.

19 Descartes to Mersenne, 28 October 1640, AT iii. 213.

20 AT xi. 11.

21 AT xi. 10.

22 For these quotations and a thoroughgoing account of this interpretation see Stephen Gaukroger, *Descartes: an intellectual biography* (Oxford, 1995), 231: here I draw further implications of Gaukroger's defence of forces among the corpuscles by applying it to the case of physiology. Richard Carter offers another suggestive picture of the relations between physics and physiology in *Descartes' Medical Philosophy: the organic solution to the mind–body problem* (Baltimore, 1983): among other differences in strategy, I am more concerned than Carter to integrate the physiology and memory theory of *L'Homme* into an overall interpretation.

23 Gaukroger, *Descartes,* 412; see for example AT xi. 50–83.

24 AT xi. 16–23. See also the clear exposition of Descartes' *Principles of Philosophy* by John Heilbron, *Elements of Early Modern Physics* (Berkeley, 1982), 22–6.

25 Gaukroger, *Descartes,* 247–8; AT viii. 70.

26 See *Principes* IV, art. 187 (AT ix. 308–9); compare *L'Homme* AT xi. 177; and

William R. Shea, *The Magic of Numbers and Motion* (Canton, MA, 1991), 111–20. Annie Bitbol-Hespériès, in her 'Introduction' to *Descartes, Le Monde, L'Homme* (Paris, 1996), pp. x–xiii, claims that Descartes was seeking to eradicate the marvellous: but in my view he attacks not the wonderful phenomena themselves, but only the ignorance which makes the learned wonder at them.

27 Leder, *The Absent Body*, 148.

28 Jonathan Sawday, *The Body Emblazoned* (London, 1995), 22, 37.

29 Merchant, *The Death of Nature*, 204.

30 Catherine Wilson, *The Invisible World: early modern philosophy and the invention of the microscope* (Princeton, 1995), 21–2.

31 AT xi. 335; AT xi. 129.

32 Descartes to Vorstius, 19 June 1643, AT iii. 689.

33 Descartes helped medicine 'veer from the organismic, mind-in-the-body approach, which prevailed from Hippocrates to the Renaissance' (Damasio, *Descartes' Error*, 251). The error of such talk of a radical split is clearly revealed by the wonderful notes on Descartes' sources in both Hall's and Bitbol-Hespériès' editions of *L'Homme*.

34 Emily Grosholz, *Cartesian Method and the Problem of Reduction* (Oxford, 1991), 120.

35 L.J. Rather, 'The "Six Things Non-Natural" ', *Clio Medica* vol. 3 (1968), 337–47; Peter H. Niebyl, 'The Non-Naturals', *Bulletin of the History of Medicine* vol. 45 (1971), 486–92.

36 Vivian Nutton, 'Medicine in Western Europe, 1000–1500', in L.I. Conrad et al, eds., *The Western Medical Tradition* (Cambridge, 1995), 139–205: 141.

37 Robert G. Frank, *Harvey and the Oxford Physiologists* (Berkeley, 1980), 40.

38 Nancy Siraisi, *Medieval and Early Renaissance Medicine* (Chicago, 1990), 101–14.

39 Linda Deer Richardson, 'The generation of disease', in A. Wear et al, eds., *The Medical Renaissance of the Sixteenth Century* (Cambridge, 1985), 175–94; Harold J. Cook, 'The New Philosophy and Medicine in Seventeenth-Century England', in D. Lindberg and R. Westman, eds., *Reappraisals of the Scientific Revolution* (Cambridge, 1990), 397–436, especially 405–11.

40 Clark, *Being There*, 163.

41 Gail Kern Paster, *The Body Embarrassed* (Ithaca, 1993), especially 1–22; Paster, 'Nervous Tension: networks of blood and spirit in the early modern body', in D. Hillman and C. Mazzio, eds., *The Body in Parts* (London, 1997), 107–25. As Michel Serres puts it in a different context, 'the organism is a barrier of braided links that leaks like a wicker basket but can still function as a dam' *Hermes: literature, science, philosophy* (Baltimore, 1982), 75.

42 AT xi. 141–63.

43 D. Sepper, *Descartes's Imagination* (Berkeley, 1996); Baker and Morris, op. cit.

44 AT xi. 163–4.

45 AT xi. 129–32. In the earlier preview of the remaining contents of *L'homme* (AT xi. 132), Descartes foreshadowed his discussions of muscular motion, of breathing and other reflex phenomena, and of the external senses. He then described the topic of the final long sections, which in fact include the treatments of memory, dreams, and so on, thus: 'after that I shall explain in detail all that happens in the cavities and pores of the brain, what pathway the animal spirits follow there, and which of our functions this machine can imitate by means of them'.

46 AT xi. 166.

47 AT xi. 130; Descartes to Vorstius, 19 June 1643, AT iii. 688.

48 AT xi. 167–70.

49 AT xi. 167–8.

50 AT xi. 169–70.

51 Véronique Fóti, 'Presence and Memory: Derrida, Freud, Plato, Descartes', *The Graduate Faculty Philosophy Journal* vol. 11 (1986), 67–81: 76.
52 See my *Philosophy and Memory Traces*, 31–49.
53 Nicholas Malebranche, *The Search After Truth*, trans. T.M. Lennon and P.J. Olscamp (Columbus, 1980), 341–2. Compare Descartes to Elizabeth, 15 September 1645, AT vi. 290–6.
54 For this formulation compare, in the modern context, Tim van Gelder and Robert F. Port, 'It's About Time: an overview of the dynamical approach to cognition', in Port and van Gelder, eds., *Mind as Motion* (Cambridge, MA, 1995), 1–43: 23–5.
55 AT xi. 170.
56 AT xi. 171.
57 AT xi. 165–6.
58 AT xi. 171.
59 AT xi. 175.
60 This two-factor framework of fleeting patterns and 'relatively stable transforming elements', which ground occurrent and dispositional traces respectively, operates 'at a decidedly abstract level', and could be realised either in neural networks or in a system of spirits and pores: compare Paul and Patricia Churchland, 'The Future of Psychology, Folk and Scientific', in R. McCauley, ed., *The Churchlands and Their Critics* (Oxford, 1996), 219–55, at 225–7.
61 AT xi. 128. The interconnected nature of all body fluids, with continual cycles running between blood, sperm, spirits, humours, sweat, tears and so on, is marked also in Descartes' acceptance of a neural circulation equivalent to that of the blood: see Edwin Clarke, 'The Neural Circulation', *Medical History* vol. 22 (1978), 291–307. On Renaissance assumptions about the interconvertibility of body fluids, see also Thomas Laqueur, *Making Sex* (Cambridge, MA., 1990), 35–43: 103–8.
62 Desmond Clarke, *Occult Powers and Hypotheses* (Oxford, 1989), 154, quoting La Forge and Gadroys.
63 AT xi. 134–7; AT xi. 335–6.
64 Sutton, op. cit., 177–88; William T. Clower, 'From Animal Spirits to Neural Electricity', *Journal of the History of Neuroscience* vol. 8 (1999).
65 Robert Burton, *The Anatomy of Melancholy (1621)*, ed. T.C. Faulkner et al. (Oxford, 1989), i. 140.
66 AT xi. 166–7.
67 AT xi. 404–5; compare *L'Homme*, AT xi. 169.
68 Grosholz, op. cit., 122.
69 AT xi. 177.
70 AT xi. 178.
71 AT xi. 178–9.
72 T.S. Hall, *René Descartes: Treatise of Man* (Cambridge, MA, 1972), 96 n. 145.
73 AT xi. 185.
74 AT xi. 185.
75 Glanvill, *The Vanity of Dogmatizing*, ed. S. Medcalf (Brighton, 1970), 39 [first pub. 1661]; on these critics see Jamie Kassler, *Inner Music: Hobbes, Hooke, and North on internal character* (London, 1995), 108–47, and Sutton, op. cit., 129–48.
76 AT x. 415.
77 AT iii. 143.
78 Like the account of hatred, Descartes' theory of corporeal memory is consistent from *L'Homme* to the *Passions* (see AT xi. 360). This is enough to challenge John Morris' claim ('Pattern-Recognition in Descartes' Automata', *Isis* vol. 60 [1969], 451–60) that Descartes' references to a non-physical 'intellec-

tual memory' from 1640 onwards were driven by his belief that the room-in-the-brain problem was insoluble. For other suggestions on why Descartes added sketchy remarks on intellectual memory to his 'thorough and complex theory of [corporeal] memory', see Richard Joyce, 'Cartesian Memory', *Journal of the History of Philosophy* vol. 35 (1997), 375–93, and Sutton, op. cit., 67–73.

79 Malebranche, *The Search After Truth*, 106–7.

80 AT xi. 185.

81 Marjorie Grene, *Descartes* (Brighton, 1985), 47–8.

82 AT iv. 310.

83 Gaukroger, op. cit., 287–9, 392–4; Baker and Morris, op. cit., 91–100.

84 Graham Richards, *Mental Machinery: the origins and consequences of psychological ideas, vol. 1, 1600–1850* (London, 1992), 65–6.

85 Owen Flanagan, *The Science of the Mind* (2nd edition, Cambridge, MA, 1991), 3. Compare Otto Mayr, *Authority, Liberty, and Automatic Machinery in Early Modern Europe* (Baltimore, 1986), 66: 'In animals it was the brain that, consisting entirely of memory and therefore capable only of initiating preprogrammed action, corresponded closely to the mechanical program controlling automata.' Mayr's interpretation of mechanistic physiology as intrinsically authoritarian overemphasises the dull passivity of the early modern machines which served as Descartes' models: in fact, as he acknowledges elsewhere (42–54, 124; compare Baker and Morris, op. cit., 91–4), machines and automata were just as strongly associated with unreliability, uncertainty, and fragility.

86 Reiss, 'Denying the Body?', 604.

87 Peter Dear, 'A Mechanical Microcosm: bodily passions, good manners, and Cartesian mechanism', in C. Lawrence and S. Shapin, eds., *Science Incarnate* (Chicago, 1998), 51–82, at 76–7.

88 Gary Hatfield, 'Descartes' Physiology and its relation to his Psychology', in J. Cottingham, ed., *The Cambridge Companion to Descartes* (Cambridge, 1992), 335–70: 348.

89 AT xi. 140–1. See Georges Canguilhem, *La Formation du Concept de Réflexe aux XVIIe et XVIIIe Siècles* (Paris, 1955), 29–30; and, for a different account of the mechanisms involved, Jean-Marie Beyssade, 'Réflexe ou admiration: sur les mécanismes sensori-moteurs selon Descartes', in J.-L. Marion, ed., *La Passion de la Raison* (Paris, 1983), 113–30.

90 AT xi. 165–6.

91 AT xi. 142. 'The cavity F' to which Descartes refers here is not the pineal gland, but the ventricle.

92 AT vii. 204.

93 Descartes to Mersenne, 18 March 1630, AT i. 134.

94 *Passions*, AT xi. 370.

95 AT i. 133–4.

96 Alan Gabbey, 'Cudworth, More, and the Mechanical Analogy', in R. Kroll et al, eds., *Philosophy, Science, and Religion in England 1640–1700* (Cambridge, 1992), 109–27: 117. This is to query Brian Baigrie's claim that Descartes saw the self-instigated movement of machines as a kind of cosmic deception: Baigrie, 'Descartes' Scientific Illustrations and "*la grande mécanique de la nature*",' in Baigrie, ed., *Picturing Knowledge* (Toronto, 1996), 86–134: 109–11.

97 Ann W. Mackenzie, 'Descartes on Life and Sense', *Canadian Journal of Philosophy* vol. 19 (1989), 163–92: 174–5.

98 Descartes to Huygens, 5 October 1637, AT i. 434.

99 Toulmin, op. cit., 41.

100 AT xi. 143. Among the numerous references to the soul in *L'homme* compare

especially, for similar locutions, AT xi. 131, 177, 183. It is unlikely that the promised section of the overall project of *Le Monde* on the soul was written and lost, as Bitbol-Hespériès concludes ('Introduction', xl-xli). *Le Monde*, including *L'homme*, should be seen as unfinished.

101 AT i. 413. Compare Gaukroger, op. cit., 287–8.

102 Gilbert Ryle, *The Concept of Mind* (London, 1949), 14.

103 As I say, this is a straightforward reading of a text carefully analysed in similar directions by others. I am particularly indebted to Peter Schouls, *Descartes and the Enlightenment* (Kingston, 1989), 144–72; to Cottingham, 'Cartesian Ethics', op. cit., and to John Cottingham, *Philosophy and the Good Life* (Cambridge, 1998), ch. 3. See also Anthony Levi, *The French Moralists* (Oxford, 1964), especially 279–82; John J. Blom, *Descartes: his moral philosophy and psychology* (Brighton, 1978), especially 84–96; Jeffrey Barnouw, 'Passion as "Confused" perception or thought in Descartes, Malebranche, and Hutcheson', *Journal of the History of Ideas* vol. 53 (1992), 397–424; and Vance G. Morgan, *Foundations of Cartesian Ethics* (New Jersey, 1994), 149–71. But it is rare for this material to be understood in the light of the physiological accounts of memory and association with which, I argue, it is closely linked. My reading of Descartes' psychosomatics differs a little from that of Dennis Des Chene (ch. 29 of this volume). I do not find such a severe developmental shift in Descartes' views from the early 1630s to the late 1640s (for a chronological account similar to Des Chene see Gaukroger, *Descartes*, 387–8): this is because I do not see the earlier physiological theory as in any sense incompatible with psychosomatic therapy, and because I do not see the later psychosomatic theory as in any sense less neurally inspired. Similarly, Toulmin's complaint that Descartes' 'physiological interests thus anticipate "biomedical science" more than they do clinical medicine' (*Cosmopolis*, 76) founders not so much on the false dichotomy between the two forms of medicine, which has of course had its historical effects, as on its neglect of the attentive, careful, and expectant aspects of the therapies which Descartes' dynamic physiology requires.

104 Malebranche, *The Search After Truth*, 607.

105 *Passions*, AT xi. 486–8.

106 AT xi. 488.

107 Stephen Voss, ed., *The Passions of the Soul* (Indianapolis, 1989), 42, n. 43.

108 AT xi. 361; AT xi. 368–9.

109 AT xi. 360.

110 AT xi. 362–3, 365–6.

111 AT xi. 394–5.

112 AT ii. 480–1.

113 John Cottingham, 'The Self and the Body: alienation and integration in Cartesian ethics', *Seventeenth-Century French Studies* vol. 17 (1995), 1–13: 11. But in his later paper 'Cartesian ethics', Cottingham acknowledges the force of 'our past psychological history' as well as our physiological make-up. In *Philosophy and Memory Traces*, I too misleadingly described the associations which Descartes thinks we need to correct as primarily biological (102).

114 AT xi. 486.

115 See the entries for *disposition* and *habitude* in Voss' outstanding lexicon, in his edition of the *Passions*, 138, 140.

116 See Reiss, 'Denying the Body?', op. cit.

117 AT xi. 369.

118 AT iv. 293.

119 AT xi. 428–9.

120 As described for primitive connections between movements and love, hatred,

joy, sadness, and desire in the *Description*, AT xi. 407–11; and compare Descartes to Chanut, 1 February 1647, AT iv. 605–6.

121 AT xi. 429.

122 For this terminology, see Schouls, *Descartes and the Enlightenment*, 168–9; Cottingham, *Philosophy and the Good Life*, 90–2.

123 AT xi. 486.

124 AT xi. 369–70.

125 6 June 1647, AT v. 57.

126 Schouls, *Descartes and the Enlightenment*, 170–2; Cottingham, 'Cartesian Ethics', 216.

127 AT xi. 370.

128 AT xi. 486.

129 AT xi. 429.

130 Amélie Rorty, 'Descartes on Thinking with the Body', in Cottingham, ed., *The Cambridge Companion to Descartes*, 371–92: 384.

131 Phillips, *Terrors and Experts*, 99–100.

132 AT xi. 486.

133 Malebranche, *The Search After Truth*, 141, 386.

134 Ibid., 203, 151.

135 Ibid., 388–9.

136 Ibid., 360: compare 339: 'we know that before his sin man was not the slave but the absolute master of his passions'.

29 Life and health in Cartesian natural philosophy

Dennis Des Chene

Introduction

In a letter of 1637, Descartes, then forty-one, writes that he has less leisure than he once had, since 'the white hairs that hasten my way are warning me that I should not study anything but how to slow them down'.[1] The *Discours,* published that same year, had already proposed that 'if it is possible to find a way to render men in general wiser and more able than they have been until now, I believe that it is in Medicine that one must look for it'.[2] Writing to the Marquis of Newcastle a few years later, Descartes goes so far as to say that 'the conservation of health has been at all times the principal end of my studies'.[3] That, no doubt, is hyperbole. But even if it would be too much to call Descartes' philosophy a medical philosophy through and through, there is no doubt that the preservation of human health was one of its chief aims.

It is curious, therefore, that within his natural philosophy there seems to be no place for a normative conception of well-being. We have, on the one hand, the project of a scientific medicine – one of the crowning glories of the tree of knowledge – and, on the other, a world – that of *Le Monde, L'Homme,* and the *Principia* – which, though it certainly allows for the description of the human body, is not merely indifferent to, but is designed to exclude, notions that would seem requisite to defining the aims of any medicine: life, health, disease. Such notions must, it would appear, refer to ends; but ends are rigorously banished from Cartesian physics.

There was, it turns out, more than one way to make up the loss. The first I call *biomechanics.* Its object is the body alone, regarded as a pure instrument, whose ends are imposed upon it in just the way that time-keeping is imposed upon a clock. The second I call *psychosomatics.* The object of psychosomatics is not the body-machine alone, but rather the union of mind and body. The union is a proper subject of teleological properties, and thus of normative predicates defined in terms of them. For the body-machine, health and sickness are external valuations, but for the union they are genuine properties.

Biomechanics and psychosomatics differ, as we will see, in their approach to treatment. Should you regard your body simply as a tool, as if you were an angel who happened to occupy it, then treatment will consist in doing whatever need be done to make the machine fulfill your purposes. But if the thing treated is the union, whose ends genuinely inhere in it, treatment will more reasonably consist in producing conditions under which the union can again operate, and restore itself, in accordance with its ends. Psychosomatics will supply, if need be, what is lacking, but always in the expectation that the agency of cure is, finally, the union itself.

Though Descartes himself favored psychosomatics, in the popular reception of his work it is biomechanics that has come to be the 'Cartesian' manner in medicine. That reception is part of, and contributes to, the characterisation of modern science as alienated from nature, its sole purpose the manipulation of the world to suit human wants and needs, themselves reduced to calculations of benefit and loss. There is, of course, warrant for the characterisation; but it seems to me to underestimate the complexity of the scientific enterprise and the motives that have governed it.

One example will show what I mean: a book entitled *Descartes' Error* can hardly help but catch the eye of a Descartes scholar. This work, by Antonio Damasio, argues that 'feelings are a powerful influence on reason, that the brain systems required by the former are enmeshed in those needed by the latter, and that such specific systems are interwoven with those which regulate the body'. Reason is, in short, 'nowhere pure'. Damasio thinks he is thereby opposing himself to Descartes, to the error of proposing 'an abyssal separation between body and mind', and of suggesting that 'reasoning, and moral judgment, and the suffering that comes from physical pain or emotional upheaval might exist separately from the body'.[4] The idea of a disembodied, or rather a disembodiable, mind has led Western medicine to neglect both the 'psychological consequences of diseases of the body proper' and the 'body-proper effects of psychological conflict'.[5]

In fact, Descartes would not have wished to neglect the psychological consequences of disease or the physical consequences of mental disorder. He would, of course, have rejected violently the contention that the mind cannot possibly exist without the body; but that it is in the nature of the human mind to be joined to a body, and that we should take seriously the consequences of that condition, are propositions to which he would not only have assented but to which he devoted a great deal of thought, and one major work, the *Passions,* which Damasio does not mention.

The more interesting question is why Damasio finds the indictment plausible. Or, to put it another way: why do we find it worthwhile, even edifying, to tell such stories about our past?

Biomechanics

In the *L'Homme,* the centrepiece of Descartes' physiology, there is, as Canguilhem observed, no distinct notion of the animate. But there are two concepts that replace, while radically altering, Aristotelian conceptions of life and organism: the *automaton* and the *machine*. Using them, *L'Homme* attempts to do for *De anima* what *Le Monde* had done for the *Physics:* to simulate the phenomena while eliminating the Aristotelian apparatus of forms, qualities, and ends.

The Aristotelian soul is at once the 'form of a body having organs', and the principle of vital operations, 'that by which we live, feel, and think'. An animal has both a certain structure and engages in certain characteristic activities – eating, breathing, sensing, moving. The structures exist for the sake of the activities they subserve: the end of the eye is seeing, which is why, in the Aristotelian account, it is filled with a transparent medium. The ultimate end towards which all the activities of the animal are directed is the preservation and perfection of the soul, which thus provides a standard for their success or failure, a standard independent of human interests and intentions. It is just because artifacts, including of course machines, do not have ends except by virtue of the designs of their makers, that artifacts are distinct from, however much they may resemble, the products of nature. To be healthy, then, in Aristotelian terms, is to have the capacities needed to sustain the soul and to be able to exercise them.

L'Homme, despite its radical departure from Aristotelian schemes of explanation, does not differ greatly in the range of phenomena it comprehends, nor in the superficial classification and ordering of those phenomena. It begins by showing how the body-machine sustains itself through respiration and digestion; and then how it is impinged upon by things around it through organs which transmit the effects of impingement to the brain; and finally how it is capable of being moved so as to avoid what would threaten its integrity and the operation of its parts (and, by implication, to pursue what would strengthen it). All this is summed up in the characterisation of living things as 'self-moving'.

The term *automaton* thus answers to the Aristotelian definition of the soul as the principle of vital operations: not, however, by designating a form, but by comprehending the same range of phenomena. The term *machine* answers, on the other hand, to the Aristotelian 'body having organs': it applies both to the whole organism, and to its parts – the sense organs, for example, or the lungs. But 'machine', designating as it does a kind of artifact, specifically excludes the attribution of ends to the things so designated – not only for Descartes, but for the Aristotelians themselves. They would agree that *if* animals were machines, they would indeed have ends only by reference to their maker or makers. The implication is that the Aristotelian schema for describing natural change – a schema to which the notion of *directedness,* if not always that of an end, is essential – does not apply to the actions of animals. In the Sixth Meditation, Descartes writes that 'just as a watch, constructed from wheels and weights, no less precisely observes the laws of nature when, being poorly made, it does not correctly indicate the hours, than when it fulfills every wish of its maker', so too the human body, considered as a kind of machine, is no less natural when, being rabid, it is caused to seek what is in fact harmful to it, than when, being healthy, it seeks what is good for it.[6] Given that the laws of nature hold everywhere, always, and for all things, no event can occur that is contrary to them: nothing can in that sense be 'against' nature. And since everything in nature can be explained by efficient causes acting according to law, there is no need either to suppose there are *ends* that a machine's ceasing to run could be said to frustrate. In that sense too nothing can be against nature. The book of nature, in short, tells us only how things are, or how they would be if such-and-such were the case; it tells us nothing of their perfections or aims, and in that sense nothing of how things *ought* to be.

A machine can be said to function well or poorly only in relation to our purposes. If we find ourselves inclined to attribute wellness or illness to the action or to the thing itself, that is an error analogous to the error we make in supposing that things really have the qualities we sense in them. That error Descartes eventually diagnoses as an instance of the common, almost inevitable, confusion of thought and extension: it consists in projecting a mode of thought – a sensed quality, a purpose – onto an extended thing which, when it is clearly and distinctly conceived, can be seen to exclude all such modes.

In particular the human body, contrary to what one might think, has, apart from the soul, no end. The eye will, in an intact body, transmit the impulses of light-particles through the optic nerve to the brain; but that it has doing so as its purpose is no more true than that apples are really red. It would be idle, of course, even to project such an end onto it if it did not operate as it does; but its doing so in no way licenses the inference that enabling us to see inheres in the eye, which is, after all, just another portion of *res extensa.*

I do not think it is entirely anachronistic to see here a version of the distinction between fact and value that is often taken to be among the hallmarks, or the stigmata, of modern science. There is a great deal more, no doubt, to the story of how nature becomes morally illegible, but one chapter, certainly, is to be found in the exclusion of ends and final causes from natural philosophy. Nevertheless I will argue that when the psychosomatic alternative is taken into account, that interpretation of Descartes' philosophy, and with it the implied characterisation of the modern in philosophy and science, is one-sided, and therefore misleading.

But for the moment let us consider a medicine consonant with the representation of the body as a self-moving machine – a biomechanics, as

I called it earlier. Biomechanics treats the body as a pure instrument, whose ends are imputed to it by us; in that respect, the eye, say, is not a different kind of thing than a telescope. Even its being the product not of deliberate human action but of biological processes does not distinguish it. At most that origin limits the degree to which it can be perfected in relation to the aim of seeing. It would seem that if the 'natural' eye could be replaced by a prosthesis that would more effectively carry out that aim – of gathering information by interaction with light – then there would be no reason not to do so. Those philosophers who today imagine that our minds will someday be downloaded into machines are, it appears, simply biomechanicians *in extremis*.

That Descartes occasionally entertained a biomechanist standpoint is revealed in an interesting example from the *Dioptrique*. The Seventh Discourse concerns the 'ways to perfect vision'. Descartes treats the question under three headings: the objects of vision, the 'interior organs that receive the actions of these objects', and the 'exterior [organs] that dispose these actions to be received as they should be'. We can improve our view of objects, obviously, by moving closer to them, or illuminating them more fully. As for the interior organs, the nerves and the brain, 'it is certain [...] that we can add nothing by art' to them. What remains are the exterior organs – 'the transparent parts of the eye, as well as any other bodies that can be put between the eye and the object'.[7]

After discussing corrective lenses and magnifying glasses, Descartes considers one further means of increasing the apparent size of images, 'which is to bring it about that the rays which come from various points of the object cross one another as far as possible from the base of the eye'. This means is by far the most important, since it enables us to see objects that would otherwise be too distant, and because it has, in principle, no limits. He then proposes the following apparatus: imagine a tube full of water, with one end applied to the eye, and at the other a glass of shape similar to that of the cornea (see Figure 29.1) The result would be that rays of light from an object will cross much sooner than they would otherwise, and the image projected on the retina will be all the larger:

> Thus the water EF performs the office of the humor K; the glass GHI, that of the membrane BCD; and the entry of the tube GI, that of the pupil; and vision will occur in the same way as it would if Nature had made the eye longer than it is.[8]

To which Descartes adds that the 'true pupil' would be not only useless but harmful, since it would block some rays from the tube that might otherwise reach the retina.

Descartes immediately grants that it would be 'incommodious' to put water against our eye in the manner described, and goes on to discuss more convenient ways of achieving the same end, ending with the two-lens

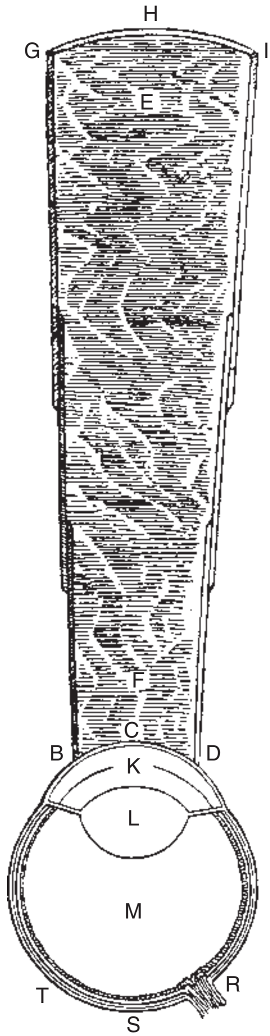

Figure 29.1

telescope. But the example is telling. The eye is an image projector; by applying the laws of refraction, we could replace it with a better one. It is treated, in other words, as a pure instrument to the end of gathering images; and only a lack of knowledge or finesse prevents us from considering similar improvements to the rest of the optic system.

It is significant that in this part of the *Dioptrique* Descartes permits himself a *façon de parler* that elsewhere he avoids. Ten times in the seventh Discourse, but only once in the preceding six, he uses the term 'Nature' to denote an agency which has 'provided' us, or in one instance, neglected to provide us, with the tools needed for good vision. It is as if the link, usually hidden, between the concept of a machine and that of a maker here had forced itself to the surface; here too the Aristotelian conception of art as the imitation of nature for once is adopted:

> We will always have to take care . . . to imitate Nature as much as possible, in every feature we see her to have observed in constructing [our eyes]; and to lose none of the advantages she has given us, except to gain something more important.[9]

Nature becomes an agent *so that* we may treat the eye *as if* it had been made in order to satisfy certain *desiderata*. The imitation of nature consists in inferring those *desiderata,* and determining whether we can do better, subject to an economy in which losses – here the errors that result from our not knowing the exact shape of the eye – must be balanced against gains.

None of this goes to prove that the eye genuinely has the end of seeing. That would be to erase the 'as if', and to suppose that the eye really was produced by a reasoning agent. The point is rather that we can, by pretending it was so produced, reason backward from a description of the eye to the ideal description of a certain kind of mechanism, which we might then hope to realise better ourselves.

The objections to a thoroughly biomechanistic medicine are several. Descartes is, of course, well aware of them. The first is that biomechanics is irrealisable in practice because of our ignorance. Even in the chapter from the *Dioptrique* discussed earlier there are hints that Nature has attained the best balance among the various *desiderata* of vision, within the limits set by the materials available and the laws governing light. If that relatively simple system cannot be improved upon, then all the more so for the far more complicated mechanisms of the nervous system or of generation.

That is a relatively minor objection to the feasibility of the project. More seriously, biomechanics fails to take full account of our nature – not our nature narrowly conceived, according which we are simply things that think, but our nature in the broad sense, as Gueroult calls it: a human being is, in this world, the *union* of a soul and a body. It is to the union, Descartes tells us in the *Principia,* that sensations and passions are to be 'referred'. If we ask in *which* thing's nature is the capacity for sensation and passion included, the answer will in the first instance be the soul's nature, since sensations and passions are modes of thought, but in the second instance soul and body jointly, since without the intervention of God, the capacity for sensation and passion will never be exhibited except when the soul is joined to the body.

For biomechanics the sense organs are simply channels of information. That they convey it to us not through clear and distinct representations of the causes of sensation, but through obscure and confused ideas, is merely an inconvenience. But that is to take the understanding, the faculty of clear and distinct perception, to be the whole of our nature. In some moods, Descartes seems inclined to that view. But elsewhere, when he is not so concerned to combat preconceived opinion by urging us to withdraw from the senses, he acknowledges that the senses are indispensable to the conduct of life, and that they have, in fact, been instituted by God so as to enable us to pursue benefit and avoid harm. What remains to be seen, however, is whether they are only a *pis aller,* a supplement to our limited powers of conception and reasoning. For that it is necessary to consider psychosomatics.

Psychosomatics

The problem to which biomechanics is one solution is that of finding a locus for the normative conceptions requisite to medicine. Biomechanics, taking the body alone for its object, locates those conceptions in thought, in what we, as if we were designers of the machine, choose to regard as its ends. Psychosomatics takes the object of medicine to be the union; that object, unlike the body alone, genuinely has ends of its own.

In the Sixth Meditation, after enumerating and, for the moment, setting aside what nature has taught him, Descartes proves that the cause of our sensations is extended substance. One consequence of that, of course, is that nature, insofar as it has taught him that bodies have qualities not included in extension, has misinformed him. But once that is established, Descartes turns to a vindication of the senses, showing how sensations, once their significance is well understood, are in fact a guide to life – not inerrant, but sufficient to their purpose. He concludes:

> since each of the motions that occur in the part of the brain that immediately affects the mind introduces into it one particular sensation, no better arrangement could be imagined than if that sensation is introduced which of all that could be introduced most greatly and most frequently leads to the conservation of health.[10]

The correspondence, in other words, between movements in the brain and sensations – more specifically, pleasures and pains – is governed by the end of conserving the union.[11] Similarly, in the *Passions,* Descartes holds that the passions are all good by nature,[12] because

> they dispose the soul to will things that nature prescribes as useful to us, and to persist in our will, just as the same agitation of the [animal] spirits that customarily causes them disposes the body toward movements that serve to carry out those prescriptions.[13]

They fulfill, in other words, the purpose for which God endowed us with them.

A machine might *seem* to act as if it were moved by a passion. *L'Homme* shows how the automaton could be caused to withdraw its hand from a flame. We recognize in that action the aim of preserving the integrity of the machine; but all that occurs can in fact, as Descartes emphasises, be explained in terms of the structure of the machine and the efficient causes acting on it and in it. The human being, on the other hand, unlike the automaton, while its action is similar, *feels pain,* which in turn produces an inclination in the soul to remove the hand from the flame. To omit the end of self-preservation is to omit a crucial element of the story, an element that supplies the rationale of the relation between the bodily and the mental events.

The Aristotelian, too, holds that the soul, being a form, is really distinct from its matter; that the soul is everywhere present in the body; and that the union of soul and body, like that of substantial form with its matter, is one thing in the strongest sense in which non-identical things can be. When Descartes held that the soul is the substantial form of the body, I do not think he was expressing merely nominal agreement with the Aristotelians. His disagreement with them does not concern the human being so much as the rest of the world: the human soul, contrary to what they hold, is the *only* substantial form.

The end of preservation is not imposed on the union, but belongs to it by nature. Health and sickness are the furthering or the frustrating of that end, just as in Aristotelianism. Like an Aristotelian agent, moreover, the body and soul will, if not impeded in their operation, act for their own good. The corresponding medicine, therefore, is one in which the body cannot be treated apart from the mind, and in which the aim of treatment is not to improve upon nature, but to remove the obstacles to nature's operations. So Descartes writes to Elizabeth:

> I know of no thought more proper for the conservation of health, than that which consists in a strong persuasion and firm belief that the architecture of our body is so good that, once one is healthy, one cannot easily fall ill . . . and, when one is ill, one may easily restore oneself by the force of nature alone.[14]

Passions and sensations are guides to action beneficial to the union. Though they are not infallible, they are our *best* guides. When Burman objects that in sickness our appetites may be deranged, Descartes replies

> Perhaps if doctors permitted people the foods and drinks they often wish for, they would often be restored to health much better than by unpleasant medicines, as experience also shows, since in such cases nature itself strives toward restoration – knowing itself better by inward awareness than any doctor outside can.[15]

Those who have reached the age of thirty, he adds, citing the opinion of Tiberius, know well enough by experience what is helpful and harmful to be their own doctors.

A medicine so conceived is not a science, not even an applied science. If our nature knows itself by inward awareness, it does so through ideas that, arising from the union, are bound to be confused. 'The idea of the soul', Descartes writes to Elizabeth (28 June 1643),

> is conceived only through the pure understanding; body . . . can also be known by the understanding alone, but it is known much better by the understanding with the aid of imagination; and finally the things that pertain to the union of soul and body are known only obscurely by the understanding alone or by understanding with the aid of imagination; yet they are known very clearly by the senses.[16]

A certain effort is required to exert the pure understanding, and thereby to know the soul, or to use the imagination to understand extension: but 'merely by living and by ordinary conversation, and while abstaining from meditation and from things that exercise the imagination', one can conceive their union. The same, no doubt, can be said of the experience that allows people over thirty to do without doctors.

Psychosomatics is not inconsistent with a mechanistic account of the body and its functions. Descartes never ceased to believe that the body, taken by itself, is an automaton. 'All the movements we make without the will's contributing to them' depend, in the *Passions* as in *L'Homme,* 'only on the conformation of the members of the body and on the courses that the [animal] spirits . . . follow naturally in the brain, the nerves, and the muscles, in the same way in which the movement of a watch is produced by the force of its spring and the figure of its wheels alone'.[17] The conflicts that the soul sometimes feels arise from contrary tendencies to motion imposed on the pineal gland by the will and the animal spirits. One could resolve the conflict by manipulating the body so as to alter the course of the animal spirits; but in the *Passions* the resolution is by an exercise of the will, which if it is strong enough may overcome them directly; if not it may turn the attention of the soul to ideas that excite passions whose force will attenuate the force of the animal spirits, and thus allow it eventually to oppose them successfully.

I have said enough, nevertheless, to show that psychosomatics is indeed an alternative to biomechanics, that Descartes not only proposed it but favoured it in his later years, and finally that it implies a relation of the soul to the body that differs substantially from the relation implied in biomechanics. The stance of the Cartesian subject as it is often presented, attempting to adopt a view from nowhere, or else reducing nature to a mere instrument, is at best only part of the story. It is consonant with biomechanics, with the Descartes who would turn the eye into a telescope; it fits much less well the Descartes who believes that the 'force of nature alone', if we could but let it operate, can restore us from illness to health.

Some Cartesians

The ambiguous legacy of Descartes is reflected in the attitudes of his successors. Francesco Trevisani's recent study of Cartesianism at the University of Duisberg provides some instances. Among those who taught there in the second half of the seventeenth century were Tobias Andreae, Johannes Clauberg, and Friedrich Gottfried Barbeck. Andreae seems to adhere most strongly to psychosomatic medicine. The *Exercitationes* of 1679 offer a reasonably full account of his views. There is, first of all, a 'direct relation' between modifications of the body and modifications of the mind, a relation of 'signification', leading not just – as one might expect – from passions to movements of the animal spirits and changes in the blood, but from those changes back to the corresponding passions. Any disease of the body is also a disease of the mind, and conversely.

The basis of some illnesses at least, Andreae holds, is an excessive sensibility to pain, which will in turn have 'serious repercussions' for the body. A pharmacological therapy would only aggravate the illness; the therapy of choice consists in 'moderating the passions'. That can be done by dwelling on intellectual pleasures, over which the soul has entire control, the aim being to extend that control again to all the passions. Or it can be done by the 'satisfaction of a long-inhibited desire', which can 'provoke changes in the blood which in turn reduce to nothing the feverish fermentation' produced by disease.[18] Where some philosophers would explain pica, for example, in purely physiological terms – the alteration of the blood, for example – Andreae explains it in terms of an 'anarchy of memory and experience'. The relation of signification between bodily changes and passions is disrupted, rendered opaque; the task of the physician, therefore, is to 'reconstitute the particular degree of transparency between psychic and physical life' that has been lost.[19] Andreae admits that the outcome of such treatment is uncertain – but so too is the outcome of drug therapy.[20]

More to the biomechanistic side is Barbeck. Barbeck starts by rejecting the possibility of a 'talking cure' for some pathological conditions.[21] Though it is true that to every passion or sensation of the soul there is a corresponding bodily action or condition, the relation of the one to the other is arbitrary. The conditions that correspond to a given passion or sensation are 'infinitely variable'.[22] With respect to them, furthermore, the passions are indeed passive: the yellow seen by a jaundiced person merely registers the disorder. It will not do, then, to let nature take its course, or to obey nature, since here the passions provide no guidance. Rather 'one must take the risk of forcing [nature]', and treat the illness pharmacologically. There is, in his work, the adumbration of a *biological* conception of living things, a conception which, unlike the psychosomatic, does not explicitly appeal to the mind–body union, but which does offer some account of the goals of living things.

For both Barbeck and Clauberg, treatment is to be guided by a conception of life and of the vital principle. Clauberg, in keeping with tradition, locates the physical conditions of life in heat and cold; Barbeck adds that life depends on movement, and movement on an 'internal and proper' cause.[23] Heat is not a primitive quality, but simply the variable movement of the particles of the blood and other humours of the body: it is, in other words, mechanistically explicable. In particular the heat of the heart, which because all the humours flow together in it, and because it has the power to expel heated particles into the rest of the body, is the principle organ of life,[24] is caused by a reaction between an acid and a 'volatile oily salt'.[25]

While there is an evident relation to older theories of native heat, the theory of Barbeck is – though clearly incomplete – consistent with mechanism. It provides, in movement, a characteristic of living things whose contrary – rest – can serve to define illness and death. The formation of stones, for example, 'depends on a single cause: rest. Hard or solid bodies were once fluid'.[26] Barbeck, in agreement with Clauberg, adheres to the rather un-Cartesian view that in terrestrial bodies movement, 'by causes unknown to us, is continually destroyed'. The total quantity of motion in the world is conserved, but only because God conserves it by continually replacing the motion which is lost.[27] In all of nature, therefore, there is a tendency to 'petrifaction', to calcification, the concomitants of rest in a physics where bodies are individuated by motion.

The aim of therapy is 'the conservation of animal heat' by the simulation of 'the conditions that render possible the conservation of life'. In particular the physician can 'prescribe drugs that delay the process of petrifaction that lies in wait for us', and which will eventually kill us.[28] The pharmacy of Duisberg was rich in purgatives, emetics, diuretics, and salivants; opium was given not only to ease pain but to impede the coagulation of the blood.[29]

Though one would not want to draw the line too sharply (Clauberg, for example, believes that the best way to stay out of the hands of the doctor is 'sobriety and temperance'[30]), still there is a point of divergence among the successors of Descartes that echoes the divergent tendencies within Descartes' own thought. On the one side, health is a product of right thinking and right action. It will come about naturally if we interpret our passions and sensations correctly; the task of the physician is to restore the correspondence between thoughts and bodily changes, and then let nature do the rest. On the other side, the physician, guided by a physical conception of the aims of life – in effect, the self-conservation of the vital principle – may intervene more radically, not only restoring normality but *supplementing* the organism in its battle against inertia, and *simulating* conditions that the organism is perhaps no longer capable itself of creating or sustaining.

Notes

1 5 Oct 1637, AT i. 434–5.
2 AT vi. 622.
3 Oct 1645, AT iv. 329.
4 Antonio Damasio, *Descartes' Error* (New York, 1995), 249–50.
5 Ibid., 251.
6 AT vii. 85.
7 AT vi. 148.
8 AT vi. 156–7.
9 AT vi. 15.
10 AT vii. 87.
11 See Martial Gueroult, *Descartes selon l'ordre des raisons*, 2 vols. (Paris, 1968) ii. 249.
12 '*Toutes bonnes de leur nature*': AT x. 478.
13 AT xi. 372.
14 AT v. 65.
15 AT v: 179.
16 AT iii. 691–2.
17 Art. 16; AT xi. 341–2.
18 Francesco Trevisani, *Descartes in Germania* (Milan, 1992), 151.
19 Ibid., 152.
20 Ibid., 153.
21 Ibid., 183, 163.
22 Ibid., 183–4, 193, 216.
23 Ibid., 185.
24 Ibid., 197.
25 Ibid., 198.
26 Ibid., 194.
27 Ibid., 190, 104; Johannes Clauberg, *Opera Omnia Philosophica* (Amsterdam, 1691), 519.
28 Trevisani, op. cit. 196.
29 Ibid., 341.
30 Ibid., 185.

30 The texture of thought

Why Descartes' *Meditationes* is meditational, and why it matters

Dennis L. Sepper

Ex imaginatione cogitatio, ex ratione meditatio, ex intelligentia contemplatio.
Richard of St. Victor, *Benjamin Major*[1]

I

In the Preface to the *Meditationes* Descartes asserts that his readers are 'those who are able and willing to meditate seriously with me and to lead the mind away from the senses, and simultaneously from all prejudgments' – people he acknowledges to be few in number.[2] This naturally leads to questions about what the invitation to meditate along with him means. First, does this have a different sense than would, say, a request to think along with him (*cogitare* in Latin, *penser* in French)? Second, 'meditation' possessed certain connotations for a seventeenth-century reader that would suggest a mental practice associated with spiritual exercises and devotions. Does the *Meditationes* display traits that clearly and significantly align it with such practices?

The second question has been predominant in recent scholarly discussions. Already in 1930 Etienne Gilson raised the devotional context by arguing that meditation met the need for persuasion that neither the summary arguments of part 4 of the *Discours* nor the 'geometric' exposition in the second Responses to Objections are able to satisfy.

> The form 'meditation', adapted to the needs of religious souls who want to be penetrated slowly by certain truths and to be reformed within in their image, had never appeared requisite for presenting abstract truths of a purely metaphysical order; one understands, to the contrary, that it imposed itself on Descartes because he had to penetrate with new truths a thought falsified by the long custom of error.[3]

In the 1950s Ferdinand Alquié and Martial Gueroult independently suggested connections to the spiritual exercises of St. Ignatius Loyola, which was all the more plausible because Descartes had attended the Jesuit Collège Henri IV at La Flèche for eight and a half years (probably 1606–14). Pierre Mesnard called attention to this coincidence of his colleagues' judgments in a paper that argued more specifically for the influence on Descartes of the Baroque, and Jesuit, practice of using visual emblems to encapsulate philosophical doctrine. This paper, read at the 1955 Royaumont Abbey colloquium on Descartes, set off a debate between Gueroult and E.W. Beth over the meditational character of the *Meditationes*. They agreed that much of it was meditational, but disputed whether an Augustinian influence (Gueroult) or the Ignatian (Beth) was more important.[4]

The discussion of the meditational character of the *Meditationes* was thus initially framed by two major concerns: first, through Gilson, the superiority of meditation to the traditional 'rhetorical techniques' of metaphysics; and, second, the indebtedness of the *Meditationes* to antecedent Christian meditational practices.[5] In the aftermath of Royaumont, scholarship tended to focus on the second concern, with ambitious claims made for the influence of Ignatius.[6] More recent scholarship, taking the Ignatian influence as a given (and developing additional connections, for example the Augustinian) has elaborated the basic premiss of Gilson's position, that the *Meditationes* is intended to be persuasive precisely as meditational rather than as a series of logical arguments.[7]

Yet not everyone is persuaded that Ignatius or even devotional practice is crucially relevant. In one of the most recent contributions to the debate, Bradley Rubidge argues that there is no deep sense in which the *Meditationes* is related to devotional meditation.[8] He contends that scholars who argue for the influence of Ignatius cite superficial resemblances no more specific to Ignatius than to other traditions of spiritual devotion. After presenting a somewhat more detailed sketch of the tradition of devotional meditation and the 'meditation genre' he comes to the conclusion that, despite a number of evocative similarities, there is no need to look to specific devotional traditions:

> The inclusion of the word 'meditation' in the book's title may be a reference to devotional meditation, but it is also possible to ignore this reference and arrive at a satisfactory interpretation of the title, simply by taking 'meditation' to mean thorough, attentive, studious reflection.[9]

One might justifiably have qualms about the adequacy of Rubidge's historical account of devotional meditation[10] but still be persuaded that there is in Descartes less a specific than a general debt to devotional exercises.[11] His assessment of how we should understand the term 'meditation' is, however, too generic to be serviceable, because it misses a basic point: that the term had a specific philosophical significance growing out of a centuries-long tradition still very much alive in Descartes' day. Recognizing this significance requires at least a brief look into earlier theories of human psychology.

II

Although medieval authors understandably often talked of meditation in a religious context, specifically as related to the understanding of Sacred Scripture, meditation had a wider sense understood by all theologians and philosophers: it was a species of *cogitatio*, cogitation (which we ordinarily translate as 'thought'). Hugh of St. Victor (1096–1141), an especially relevant author because of his influence on the conception of meditational and contemplative practice well into the seventeenth century, defined meditation as 'a repeated cogitation that investigates the mode and the cause and the reason of every single thing. Mode: what it is. Cause: why it is. Reason: in what way it is.'[12]

In *De modo dicendi et meditandi* Hugh gives a fuller statement about meditation and the specific role it plays in the general economy of psychic activity, quite apart from any specific object, religious or otherwise:

> Cogitation is when the mind is passingly touched by the notion of things, when the thing itself is presented immediately to the [rational] soul by its image, either coming in by sense or arising from memory. Meditation is the assiduous as well as sagacious reconsideration of cogitation, striving to explain something obscure, or probing to penetrate something hidden. Contemplation is the rational soul's keen-sighted and free intuition [*intuitus*] into things needing examination that are diffused all about.[13]

In this passage meditation is more than just a species of cogitation. It stands intermediate between cogitation and contemplation. Cogitation and meditation are alike in being discursive powers of the rational soul or mind (*animus*); contemplation, by contrast, is immediately apprehensive. All three stand in relation to the central manifold of sensory and memorative experience. Cogitation begins with the sensory and memorative images of things, in the presence of which the mind is touched by a notion (or concept); reconsideration of these cogitations with the aim of discovery constitutes meditation; and the recognition of something unifying or pervading the manifold is contemplation.

An example might be our seeing or remembering a particular tree and its characteristics. We recognize it as such and such a tree, often expressly, but sometimes only implicitly (that is, without clearly formulating for ourselves something like the proposition that the tree is the red oak shading our parents' house, though nevertheless being aware of it). Meditation takes this cogitation and scrutinises it, circumambulates it, puts it into relationship with other things. Having recalled the red oak in our parents' yard, we remember its shape, the swing hanging from its branches, the tree house we planned but never built; events that took place under it; the disease that struck it down; etc. Per se there is no prescribed itinerary for meditation, the course of which will be guided by the investigative intention. So, for example, if in later life I become a botanist I may recall botanically relevant details and relate them to other oaks and trees I have known and things I have learned and read about; the disease that laid it low will now have a different significance and lead to different reflections and conclusions than if I had become a lumberjack or a carpenter. Contemplation would be an act of seeing through all these examples, incidents, and details ('diffused all about') to a unifying insight; an example might be recognizing that the disease was not what we thought at the time of the tree's demise but a virus discovered later that fits the symptoms we recall.

A different example: I notice that a tower I had always thought was round is really octagonal. Being in a reflective mood, I begin wondering about other things I have perceived otherwise than they really are and about what this says about the trustworthiness of sense perception. This leads me to think that some perceptions must be trustworthy, since after all I now know that the tower is octagonal rather than round. But then I begin wondering again, for I notice that I have two sets of perceptions (round tower and octagonal tower) that contradict one another, and ask myself what criterion I use to discriminate the reliable from the untrustworthy. Of course I have begun to enter through this train of thought the realm of Descartes' first meditation. I have begun with cogitations, that is, a series of incipient notions set off by images of sense or memory, and have turned my mind to assiduously and sagaciously treating and re-treating them in order to bring out something hidden or obscure – what Hugh calls meditation. From time to time I gain an insight into how things stand, even if it is one that stands up only for a short time – an act of contemplation.

Other members of the Victorine school further elaborated Hugh's psychology of cogitation-meditation-contemplation, above all Richard of St. Victor (d. 1173) in the *Benjamin major* and *Benjamin minor*. A sign and reinforcement of its influence a century later is St. Thomas Aquinas' citation and dialectical modification of Richard in the portion of the *Summa Theologiae* traditionally called the 'Treatise on Contemplation'.[14] The teaching of the Victorines was repeated throughout the following centuries; perhaps most significant for our purposes is that it was foundational for the Jesuits' interpretations of Ignatius' spiritual exercises in the late sixteenth and early seventeenth century.[15]

III

Meditatio has meaning as part of a constellation of psychological terms, or, more precisely, it plays a role within a psychological economy that is for the most part foreign to us, but of which Descartes was very much aware and which shaped his approach to matters of mind. This constellation or economy was embedded in the psychophysiological theory of the internal senses: common sense (*sensus communis*), imagination (*imaginatio* or *phantasia*), memory (*memoria*), and estimation or cogitation (*vis aestimativa* in animals, *vis cogitativa* in human beings). The theory was developed especially by Islamic commentators on Aristotle – Avicenna first of all, but also of importance to the Latin West was a version produced by Averroes – who took as their starting point the discussions in *De anima* and Aristotle's other psychological works of the powers of soul intermediate between the five external senses and intellection. It was a psychophysiological theory because it correlated these internal senses with brain locations, in particular the anterior, medial, and posterior ventricles (concavities) beneath and between the two hemispheres of the brain.

A long story could be told, indeed needs to be told, about the theory (or rather theories) of the internal senses, but here I shall mention only a few relevant facts. First, one of the most basic motives for the commentators' efforts was to comprehend Aristotle's enigmatic assertion that there is no thinking without phantasms (the locus classicus for which is *De anima* 431a14). In Greek this is to say there is no *dianoia* without *phantasmata*; in the Latin of the scholastics that there is no *cogitatio* without *imagines*, images. Understanding or knowledge required illumination of the phantasm by agent intellect, which phantasm is the product of the intermediate Aristotelian power called *phantasia*. The internal senses exercised the various functions needed to perfect the phantasm for this illumination. The further away from common sense one gets in the sequence the more fully abstracted the phantasm is from matter; an imagined tree is more abstracted than a seen one, an image formed as a kind of synthesis of many different memories of trees more than the memory of a single tree. In the Avicennan versions of the theory the highest internal sense was the cogitative (as it was also for Aquinas, who called it particular reason), which composed and divided the phantasm and in effect made judgments about particulars.[16] The Averroist versions attributed this power to imagination. In late scholasticism there existed a tendency to reduce these functions to fewer internal senses; for example, in an author who may well have been known to Descartes already in his school days at La Flèche, Eustace of St. Paul, the internal senses were in effect reduced to imagination.[17]

The complete story of the psychological background would have to be amplified by a consideration of Augustinian traditions as well. The crossings and interactions of Aristotelian and Augustinian theories would of course be quite complex. One thing we should note here is that Augustine's psychological triad of memory, intellect, and will was fundamental in the meditative tradition of Bernard, Bonaventure, and the Victorines. This tradition teaches that one must turn away from the realm of the senses (and of corporeal memory and imagination) in order to discover the deepest sense in which man is made in the image and likeness of God. Yet although one must turn from the corporeal realm, the intellect is capable of seeing the figuration of the divine even in the corporeal. In this light, the Aristotelian theory of abstractive knowing through phantasms could be seen as a sober, more scientific version of this turning away from corporeal things. In both traditions one begins with the deliverances of the senses (the images as sensed or remembered, where *cogitatio* commences); in the search for truths that go beyond these deliverances there must be an intensive survey and re-treatment (*meditatio*, which can be compared to the survey in *epagoge*/induction); seeing through the diffuse evidence to a unifying truth is the act of *contemplatio* (also called *contuitus* or *intuitus*, and comparable to the abstraction of the intelligible species that culminates in Aristotelian *theoria*).

IV

I do not pretend that the preceding gives an adequate account of the psychological theories underpinning Medieval and early modern conceptions of meditation. But it does present the basics, and it is sufficient for beginning to clarify what meditation meant for Descartes.

The 1690 biography of Descartes by Adrien Baillet relates a pertinent anecdote. Hector-Pierre Chanut, the French ambassador to Sweden and friend of Descartes who was instrumental in arranging Queen Christina's invitation of Descartes to Stockholm, told another friend of Descartes', Claude Clerselier, that Descartes 'had often explained in conversation' the maxim (which Baillet says might seem paradoxical and 'the profundity of which is perhaps not penetrable to everyone') that he 'had never employed but very few hours per day on thoughts that occupy the imagination, and very few hours per year on those that occupy the understanding alone'. He continues:

> M. Chanut referred the first thoughts to meditation, for which M. Descartes wanted, according to him, one to give few hours per day; and the second to contemplation, in which our philosopher did not deem it necessary to employ many hours in an entire year, nor even in all one's life. According to this idea, M. Descartes called the works of the imagination meditation; and those of the understanding, contemplation.[18]

This report is at second hand, of course, but its use of terms is confirmed by Descartes' own usage in a similar passage of a 28 June 1643 letter to the Princess Elizabeth.[19] One thing to note is that there is nothing specifically devotional in this explanation; its orientation is psychological instead. Another is that, amplified by the use of the senses (as in the correspondence with the Princess Elizabeth), this becomes a psychology of sensation-imagination/meditation-understanding/contemplation that mirrors the structure of the medieval triad *cogitatio-meditatio-contemplatio*.

The epigraph of this paper, drawn from Richard of St. Victor's *Benjamin major*, remarks that cogitation is from imagination, meditation from discursive reason (*ratio*), contemplation from intelligence or intellect. In the Victorine schema meditation is an act of recursion to cogitation, while contemplation is a recognition of unity in this recursive survey. Is there a similar progress through recursion in Descartes?

The view of Descartes as pure thinker and as mathematiser of thought, with 'thinking' taken in its very loose modern acceptation, gets in the way of noticing this kind of recursion in his work. Once we have recognized it, however, it makes a very great difference to how we should conceive the *Meditationes* and his philosophy in general.

The writings from the period 1618–30, the period before Descartes started writing *Le Monde* and long before he published anything at all,[20] make it clear that he was familiar with, even steeped in, the antecedent traditions of psychology, and especially the internal senses doctrine.[21] Even his thinking about method appears to have been spurred on by psychological questions. For example, he considered ways of supplanting the traditional art of memory (which employed carefully located images embodying the content of speeches, texts, events, sciences, and anything else that needed remembering) with a more consistent deployment of imagination, using techniques that express in striking images relations of proportion and order holding between things and that continuously evolve images from one another according to causal principles.[22] The *Regulae ad directionem ingenii* attempts to systematise a psychophysiologically driven method by employing *intuitus* and *deductio* to govern 'the motion of cogitation', which he also calls 'the motion of imagination'.[23] His physiological discussion of phantasia in the *Regulae*'s Rule 12 is a modernisation and radicalisation of Medieval theories of the brain location of the internal senses. He reduced the internal senses, including memory and common sense, to imagination and its functioning, the discursive, investigative activity of which is cogitation proper. All the activities of the mind involving images, whether those activities are apprehensive or discursive, passive or formative, he combined under the term *ingenium*.[24]

The work of this early period is predicated on three principles: that the things of the universe are related to one another through participation in natures; that this participation is governed by analogy and proportion; and that all such relationships can be represented through images, and in particular through geometrical figuration. These principles are at work in the mathematical and physical writings of these years and underlie Descartes' use of geometrical figures and schemata to portray the relevant aspects of problems, for example, the relationship of velocity, time, and distance for a falling body, the transmission of force by instantaneous tendency to move of particles in a fluid, and the harmonic relationships of the musical scale. This kind of figuration of relationships and proportions is preeminently the task of imagination, and what is usually interpreted as Descartes' mathematisation of thought is more fundamentally the imaginalisation of thought.

For the Descartes of these early writings, the vast majority of what we call thinking, or cogitation, takes place in, or at least with the accompaniment of, the imagination (or *phantasia*).[25] Although there is activity of intellect on its own – he explicitly defines this as pure intellect[26] – he does not in the *Regulae* completely explain what this means.[27] The *Regulae* emphasises to the contrary the need to exhibit wherever possible every element of a problem to imagination and even to the senses because intellect tends to err when it neglects what the imaginal or corporeal form presents.[28] I am not arguing so much that there is no activity of pure intellect alone at this stage of Descartes' thought – although such a case could be made – as that he treats thought as having primarily to do with things that can be figured in one way or another and believes that intellect without an imaginable object is always at risk of going astray.[29]

V

The mature Descartes indeed restricts the direct cognitive value of imagination, not least because the criterion of the clear and distinct grasping of ideas requires abandoning the principle of resemblance between the corporeal and noncorporeal realms. Yet he nevertheless retained cognitive uses of imagination (especially in the science of physics)[30] and a certain analogy between the two realms. One hint of this occurs in Descartes' reply to Hobbes' objection to the notion of the idea of God. He criticises Hobbes' resolute interpretation of 'idea' as always and everywhere corporeal and remarks that he chose the word because it was the standard philosophical term for the forms of perceptions belonging to God's mind, 'even though we recognize that God does not possess any phantasia.'[31] Implicit is an analogy: ideas are to the intelligence as images are to the imagination.

At issue in Hobbes and Descartes' disagreement is whether and how we come to 'have' an idea of something incorporeal. Descartes of course notes that 'idea refers to whatever is immediately perceived by the mind', but this is immediately qualified by the example he gives: 'because, whenever I want and when I fear, I simultaneously perceive that I want and that I fear, this volition and fear are numbered by me among ideas'. Just as in the *Regulae* the noncorporeal things he adduces in addition to God are acts of mind. More important, the example suggests that noncorporeal ideas are not had *simpliciter*, but only by way of a second-order consideration, by what I call a simultaneous recursion. Thus ideas are not properly speaking had, they are rather a way of having or taking or seeing first-order (or at least lower order) objects of thought. Ideas are not thing-like or even necessarily image-like, they are first and foremost a formative illumination, they are light-like.[32] Ideas are thus also fundamental aspects or qualifications (*naturae*, natures) of appearance, in light of which we conceive the direct objects of thought. Whether corporeal or incorporeal, they are a dimension of depth that allows us to see lower order objects in ways that make them comparable. They establish a basic structure of biplanarity – the plane of the object and the plane of its illuminated aspect – in consciousness. By attending to the plane of illumination we can in turn make it an object of thought that will appear in a new plane of illumination. A higher order object thus becomes subject to a yet higher plane. But the degree to which this can happen without first-order objects (corporeal images) is precisely what is at issue.

Recall that for the Victorines cogitation was the mind's being passingly touched by a notion or concept in the presence of a sensed or remembered image, and meditation was the discursive reconsideration with investigative purpose of these cogitations. If Descartes is thinking along such lines, then to have noncorporeal ideas one has to begin with sensations and memory images and the passing notions they evoke, then has to reconsider these in an inquiring mode (meditation), and finally has to see that in the very appearance and reconsideration of these images the noncorporeal aspect will manifest itself to contemplation.

Here let us recall two basic movements in the 'argument' of the *Meditationes,* the so-called *cogito*-argument and the proofs of God's existence in Meditations III and V. It would not be uncommon, I think, to claim that to see the truth of 'I think, therefore I am' (as the *Discours* and the *Principia* put it) or 'I am, I exist' (in the words of the *Meditationes*) one must rid one's mind of all sensations and imaginations and think only the pure thought. But this is quite the opposite of the way Descartes comes to the truth of 'I am, I exist'. At the outset of Meditation II he quickly repeats the process that he undertook in the first Meditation by recalling to mind the original sensations, then the doubts, and so forth. He does not remove them from mind but only disconnects them (by means of the imagined evil genius) from the claims they seem to make about their existence as more than appearances. In the very act of trying to think away the body and the senses, so that there is 'nothing at all in the world, no heavens, no earth, no minds, no bodies', he comes to see that the very act of trying to persuade himself, or denying, or doubting, or being deceived, includes existence. It is in the course of the *meditatio* of the previous *cogitationes* that he sees the truth of 'I am, I exist'. (In Hugh's sense, this ultimate 'seeing' through a manifold to a unifying insight is a *contemplatio*, a *contuitus* or *intuitus.*)

In particular, in the course of these cogitations (a term I now use in the most generic sense to include meditation and contemplation) he comes to see cogitation itself, of whatever order its object may be, as an activity, as his own activity; then, in another recursion, he comes to see that this activity has no illuminative aspect in common with the first-order, corporeal things with which the entire train of meditation started. The activity of thinking, by explicit or even implicit recursion, progressively constitutes the different planes of attending to objects of thought.[33]

The example of the piece of wax at the end of the second Meditation helps confirm this planarity and biplanarity of thought for Descartes: what we come to recognize through all the changes of appearance of the wax, as we observe it pass from solid to liquid to hot gas, is that there is a non-sensible knowing power present to all our observations. So also does Descartes' qualified acceptance of Gassendi's assertion that I should be able to conclude that I exist from observing any other of my actions (e.g. 'I am walking, therefore I exist'.[34]) Once we have, through the argument of the *cogito*, come to see the necessity of my existence in every act of cogitation, then even when I attend to myself walking I can recognize my existence insofar as I see that my consciousness of walking is a thinking activity, on a plane distinct from that of the walking.

The proofs of the existence of God in Meditation III are perhaps even more persuasive of my point. The first, which proceeds according to causation of ideas, and the second, which proceeds according to the cause of my being, a being that is capable of having the ideas it does (including that of God), both become vacuous if we conceive them as simply eliminating the planes of sensation, imagining, cogitation. What I do is not eliminate them but suspend my confidence that they are something outside of my consciousness; this is what introducing the planar relationship called the 'objective reality of ideas' is supposed to accomplish, that is, the representative value that ideas have regardless of whether they are formally realised in a world apart from my consciousness. I am led to the idea of God (and then to His formal existence) not by turning away from these things but by meditating and seeing that the content of sensation and imagining leads me along a chain of present causation that must go beyond the sensible and the imaginable, and must go beyond my finite self. It is the chain of all this mental experience that provides the background (a plane!) against which the evidencing of the truth can be clearly and distinctly grasped.[35]

Even the last three Meditations, which often seem to be more treatise-like, nevertheless retain this meditational character. One can certainly grant that in the latter parts, and especially in the sixth Meditation, Descartes is laying a foundation for his physics, but his even more basic intention remains the same: to consider things, and then attentively to reconsider them in light of new, and deeper, questions. For example, in the fifth Meditation he reflects on how certain ideas, mathematical ones, involve a necessary entailment of properties that are not immediately evident until they are unpacked; by analogy, he turns to the idea of God to show that there is an entailment in the idea of Him that is unlike the entailment in any other idea, that of formal existence. He is thus seeing the idea of God against the background of mathematical ideas, which are the least corporeal of all imaginable things. In the sixth Meditation there is a protracted meditation on how close imagination can bring us to the assertion of the existence of something corporeal; then, against this background, Descartes shows that sensation can achieve the proof of what imagination cannot, despite the fact that we are sometimes deceived in our sensations (a re-evocation of the first Meditation). In virtually every movement of thought in the *Meditationes*, and as in the classical, premodern form of meditation, Descartes resumes his previous considerations and takes up again considerations that were put aside or left incomplete in order finally to achieve completion on a new plane for reflective thought. The *Meditationes* has a sense of closure precisely in this meditational character: the attempt to survey, think through, and penetrate the field of experience.

VI

In this chapter I have only broached some major issues, not resolved them. My aim has been to open our eyes to a fundamental characteristic of Descartes' thought and to what it might mean to take seriously the claim that Descartes' philosophy is meditational in more than a casual sense.

In concluding I wish to broach one more issue: what we hope to gain from re-evoking such questions about Descartes. If it were only to fill out a chapter in intellectual history, or to identify respects in which a thinker was original or not, or to correct misimpressions about a past figure, even a supremely important one, then however meritorious such study would be it would be a matter of only potential interest to philosophers. Even supposing that there was a psychologically rich notion of meditation in the Middle Ages; even supposing that Descartes was immersed in this tradition and liberally used it; even supposing further that we could show that his manner of using it also helped bring about the demise of this psychology: all that is well and good, but it might well be irrelevant to our concerns.

But just suppose that there is embodied in these traditions a genuine experience of something that has become very obscure to us, an experience that has been variously named and described over the centuries but that nevertheless bears certain characteristic traits; suppose that, especially in Descartes, it is an experience in which thinking encounters being in a fundamental and fundamentally articulate way. In such an experience and its re-evocation there might well be something capable of checking the propositionalism and linguisticism of contemporary philosophy that, however historically justified they may be, have exceeded reasonable bounds; there might be opened a way to encounter not just the logic or the textuality and contextuality of thought but also thought's texture and contexture, as it weaves its way around its objects.[36] Cartesianism has preserved the texts of Descartes but perhaps not the texture and contexture of his thought. If Cartesianism had followed the texture rather than the text and not lost track of the (historical) contexture, perhaps it would have felt less of a need to reject genuine and truth-bearing experiences in the name of Descartes. Might it not turn out that the best guide back into this contexture of thought is precisely the thinker who stood at the boundary between the older and the newer, who thought the former across to the latter? To read Descartes with eyes for this, to discover the meditating Descartes, would be an activity of rediscovery, no mere historicising but thought encountering what is originary. In a word, the philosophy of first things, first philosophy.

Notes

1 J.-P. Migne, ed., *Patrologiae Cursus Completus*, second series (Paris, 1854; henceforth referred to as *Patrologiae Latinae*), cxcvi. 66.

2 AT vii. 9. The meditational character is reaffirmed by Descartes in the second set of Objections and Responses, AT vii. 157.

3 Étienne Gilson, *Études sur le role de la pensée médiévale dans la formation du système cartésien* (Paris, 1930), 186–7.

4 See Pierre Mesnard, 'L'arbre de la sagesse', in *Descartes, Cahiers de Royaumont, Philosophie, no. 2* (Paris, 1957), 336–49, and the discussion following, 350–9.

5 As we shall see, Mesnard's insight concerning the importance of images and imagination proves to be at least equally germane.

6 For example, in L.J. Beck, *The Metaphysics of Descartes: A Study of the Meditations* (Oxford, 1965), 28–38. The most ambitious and detailed account of the Ignatian influence is Zeno Vendler, 'Descartes' Exercises', *Canadian Journal of Philosophy* vol. 19 (1989), 193–224.

7 This position is axiomatic for the contributors to Amélie Oksenberg Rorty, ed., *Essays on Descartes' Meditations* (Berkeley, 1986), and is argued at length in the first three essays: Rorty's 'The structure of Descartes' *Meditations'* (1–20), L. Aryeh Kosman's 'The naive narrator: Meditation in Descartes' *Meditations'* (21–43), and Gary Hatfield's 'The senses and the fleshless eye: The *Meditations* as cognitive exercises' (45–79).

8 Bradley Rubidge, 'Descartes' Meditations and devotional meditations', *Journal of the History of Ideas* vol. 51 (1990): 27–49.

9 Ibid., 45–7. Some of the similarities are a retreat from the distractions of the world, a division of meditation into days, a use of reviews and summaries at the beginning and end of each meditation, an orderliness of the meditative process, an engagement of the meditator through first-person narration, a 'purgation' or rejection of the senses and the imagination, an arrival at contemplation after meditation, and a central concern with the existence of God and the possible immortality of the soul.

10 For example, he claims that the neo-Platonism of St. Bonaventure and the School of St. Victor did not play 'a major role in the kinds of meditation most widespread in the seventeenth century'. This is a startling oversimplification that is scarcely compatible with (to take just two examples) the degree to which early Jesuit debates about the spiritual exercises took the Victorines, Bernard, and Bonaventure as authorities on meditation and contemplation, and the influence of Augustine on the devotional school established by Cardinal Bérulle (whom Descartes knew) and continued by members of the Oratorian order he founded (including Guillaume Gibieuf, whom Descartes knew and read). Quite apart from this background, however, Rubidge takes as the standard for devotional meditation in the seventeenth century works that appeared after 1650. But there were important changes in the traditions of devotion during this period that made devotional practices more popular, more affectively pious, and less intellectual. It is therefore anachronistic to assume that we can take late seventeenth-century conceptions and practice as authoritative for Descartes' generation.

11 This does not imply that the devotional traditions are irrelevant. If, as I believe is possible, one shows an affective component in Descartes' pursuit of truth, and if, as I think is certain, the *Meditationes* intrinsically aims at bringing the human will into conformity with God's, then one can establish not an accidental but an essential relationship to the practice of devotion. This is easier to recognize if, instead of tracing out meditation as a genre, as Rubidge does, one recognizes that it is first and foremost a spiritual praxis.

12 Hugh of St. Victor, 'De meditatione', in *Six Opuscules Spirituels*, Sources Chrétiennes, no. 155 (Paris, 1969), 44–59: 44. It appears in Migne, *Patrologiae Latinae*, clxxvi: 993–8, under the title *De meditando seu meditandi artificio*.

13 'De modo dicendi et meditandi', *Patrologiae Latinae* clxxvi. 875–80; see 879. The *Dictionnaire de spiritualité, ascétique et mystique: Doctrine et histoire*, ed. Marcel Viller (Paris, 1937–) x. 912 does not regard this work as Hugh's, but there is an almost identical statement in the authentic 'Nineteen Homilies on Ecclesiastes', *Patrologiae Latinae* clxxv. 116–17 (where, in particular, *intuitus* is replaced by *contuitus*).

14 *Summa Theologiae*, IIa IIae, qq. 179–82, esp. q. 180, art. 3, obj. 1 and ad 1. Aquinas cites approvingly Richard's statement that 'contemplation is the rational soul's perspicuous and free beholding [*contuitus*] of the things being examined; meditation, however, is the rational soul's intuition [*intuitus*] occupied in the search for truth; whereas cogitation is the rational soul's looking [*respectus*] that is prone to wander'.

15 S. v. 'Meditation', *Historisches Wörterbuch der Philosophie*, ed. Joachim Ritter and Karlfried Gründer (Darmstadt, 1980), v. 963; and *Dictionnaire de spiritualité*, i. 813. The latter shows that the participants in the Jesuit debate over the relation between imagination, cogitation, meditation, and Ignatian 'application of the senses' for the most part simply accepted the Victorine framework.

16 The degree to which the internal senses already perform cognitive functions is evident from Aquinas' discussions of the cogitative, which knows individuals as falling under a universal. To cite an author whose claim of more than fifty years ago that the cogitative has been much neglected is still timely: 'Does therefore the cogitative, a sensible and organic faculty, know the common nature, that is, man or oak as universal? St. Thomas is careful to say no such thing. He says that the cogitative knows the individual as existing, and as coming under the human nature. Strictly speaking, therefore, it knows only the individual. Yet, the human being who makes use of his cogitative sense becomes conscious – a thing that the brute beast could never do – that this object-individual which he apprehends by his cogitative realizes the universal nature of man or of oak, and he knows this universal nature of man or of oak by his intellect.' Julien Peghaire, 'A Forgotten Sense, the Cogitative according to St. Thomas Aquinas', *Modern Schoolman* vol. 20 (1943): 121–40, 210–29; see 140.

17 S. v. 'imagination' in Étienne Gilson, *Index Scolastico-Cartésien* (Paris, 1979), 138–9.

18 AT x. 203. Emphasis in the original. Baillet cites as source of this anecdote a memoire composed by Clerselier.

19 AT iii. 693. Descartes adds: 'I have given all the rest of my time to the relaxation of the senses and to the repose of the spirit; I even count among the exercises of the imagination all serious conversations and everything for which attention is required.'

20 His first publication was the *Discours de la Méthode*, in 1637.

21 Elsewhere I have discussed many of the relevant texts and issues in arguing for the centrality of imagination in his earliest philosophising. See 'Ingenium, memory art, and the unity of imaginative knowing in the early Descartes', in

Stephen Voss, ed., *Essays on the Philosophy and Science of René Descartes* (Oxford, 1993), 142–61; and 'Descartes and the eclipse of imagination, 1618–1630', *Journal of the History of Philosophy* vol. 27 (1989): 379–403.

22 AT x. 230.

23 AT x. 388.

24 *Ingenium* is rarely used technically or systematically in Medieval psychology, but one place that it plays a leading role is in Hugh of St. Victor. In Book 3 of his *Didascalicon*, perhaps the premier Medieval treatise on the nature of science and method, Hugh discusses the nature of *disciplina* and the division of philosophy into parts. After ch. 7 asserts that what is necessary for the investigation of things are nature, practice, and discipline, ch. 8 divides 'nature' into *ingenium* and *memoria*, which are the embodied powers of perceiving well and being able to hold on to those perceptions. Chs. 9–11 then deal with order, method, and meditation, respectively. See Migne, *Patrologiae Latinae*, clxxvii. 772. *Ingenium* is prominent also in Hugh's *De modo dicendi et meditandi* (ibid., 877). The relationship of Hugh's work to Descartes and possible influences of this constellation of topics on Descartes seem worth further pursuit.

25 This is true already in Descartes' very first complete work, the 1618 *Compendium musicae*, in which imagination is portrayed as actively figuring out the character of musical rhythm as one note after another is sounded and perceived: AT x. 93–4.

26 AT x. 416.

27 This is not to say that he did not explain it at all. The intellect in operating on its own either recognizes purely spiritual or intellectual acts (like doubting and willing) or what images and imageable things are not. But both of these activities still have images and imageable things for direct or at least indirect objects (that is, for there to be doubting there must be something concrete that one doubts, and in observing that thought is not the same as extension one must think away from the predicate). For a discussion, based on Rule 14, AT x. 442–6, see Sepper, *Descartes' Imagination*, 199–207.

28 AT x. 399, 416–17, 442–3.

29 It is interesting to note the detail that when at AT x. 416–17 Descartes discusses the intellect's activity when it is concerned with things in which there is nothing corporeal or similar to the corporeal, he says that the senses are to be 'closed off' or 'kept away' (*esse arcendos sensus*), but the imagination is to be, 'as much as can happen, stripped [exuendam] of every distinct impression'. This seems to imply that the imagination is so characteristic of knowing activity that the best one can do is hold it relatively quiescent, reduce its succession of articulated images to a kind of blur. Another point of relevance is that besides purely spiritual and purely corporeal natures the *Regulae* asserts the existence also of natures that can be instantiated in either form; and since in the period of his earliest thought Descartes allowed the figuration of spiritual things through the corporeal, a key question is whether very many things at all would be neither corporeal nor similar to the corporeal.

30 For a discussion of the continued, though more limited, primacy of imagination in physical and mathematical subjects see the discussion of *Le Monde* in my 'Ingenium, memory art, and the unity of imaginative knowing,' and *Descartes' Imagination*, 211–38.

31 AT vii. 181.

32 Thus Descartes' youthful interest in optics and his conception of *Le Monde* as a treatise on light have a much more than physical significance, because he was ultimately pursuing the nature of illumination in both a literal and a figurative sense.

33 Doubtless some readers will remark that after once performing the Meditations

seriously one can simply summon up the idea of self, or God, etc., without the intermediate stages, and that this would be having the idea of self or of God in the proper sense, had by pure intellect divorced from sensation and imagination. I would not want so much to contest the possibility of this way of thinking a noncorporeal idea as say that it tries to make general for Descartes what is at best a limiting case. But whether one really has, say, the idea of God without simultaneously holding in mind his power, his creation of all our own powers, his being the cause of all causes, etc., and without descending to those quite humble corporeal appearances that are last in the chain of things caused, is precisely the question that, I claim, needs to be considered. Insofar as Descartes insisted on conceiving thought in fullest clarity and distinctness, I believe that these humble corporeal appearances are imprescindable.

34 See AT vii. 258–9 and 352.

35 Descartes' understanding of the temporality of thought's self-evidencing is much more radically 'presentist' than the preceding traditions of psychology. There is no validation of any kind of memory before Meditation V, so whatever truth is established before that must derive from the simultaneous presence to mind of the different relevant planes. The temporal process of meditation helps one rise to the moment when one is finally able to see their relationships, in a moment and past the confusing mass of cogitations, in simultaneity.

36 An exploration of texture and contexture, in implicit opposition to text and context, would emphasize how an individual thinker's thought weaves itself around its objects and questions (thus establishing a texture) and does so within a texture of thinking shared with others (contexture) both explicitly (usually as expressed in texts and in conversation) and implicitly (in the potentialities and achieved structures of language and in local and global conventions of thought). But this is only an indication of the direction in which inquiry about texture and contexture would have to move.

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