F

F_1 (first filial generation) The first generation of offspring resulting from an arranged cross between *homozygous parents in breeding experiments. *See* MONOHYBRID CROSS.

F_2 (second filial generation) The second generation of offspring in breeding experiments, obtained by crosses between individuals of the *F_1 generation. *See* MONOHYBRID CROSS.

Fabry–Pérot interferometer A type of *interferometer in which monochromatic light is passed through a pair of parallel half-silvered glass plates producing circular interference fringes. One of the glass plates is adjustable, enabling the separation of the plates to be varied. The wavelength of the light can be determined by observing the fringes while adjusting the separation. This type of instrument is used in spectroscopy.

face-centred cubic (f.c.c.) *See* CUBIC CRYSTAL.

facilitated diffusion The transport of molecules across the plasma membrane of a living cell by a process that involves a specific transmembrane carrier (*see* TRANSPORT PROTEIN) located within the plasma membrane but does not require expenditure of energy by the cell. The carrier combines with a molecule at one face of the membrane, then changes shape so the molecule is moved through the membrane and released at the opposite face. It enables the diffusion through the membrane of molecules that otherwise could not pass through. *Compare* ACTIVE TRANSPORT.

fac-isomer *See* ISOMERISM.

factorial The product of a given number and all the whole numbers below it. It is usually writen $n!$, e.g. factorial $4 = 4! = 4 \times 3 \times 2 \times 1 = 24$. Factorial 0 is defined as 1.

Factor VIII (antihaemophilic factor) One of the blood *clotting factors. Factor VIII is a soluble protein that stimulates the activation of Factor X by Factor IXa, which in turn converts *prothrombin to thrombin, thus causing the fibrin matrix of a blood clot to form. *Haemophilia is due to a deficiency or defect of Factor VIII and is treated by administration of blood plasma or plasma concentrate containing the factor. Factor VIII can now be obtained from genetically engineered cell cultures, which avoids the risk of contamination with viruses, notably HIV (the AIDS virus).

FAD (flavin adenine dinucleotide) A *coenzyme important in various biochemical reactions. It comprises a phosphorylated vitamin B_2 (riboflavin) molecule linked to the nucleotide adenine monophosphate (AMP). FAD is usually tightly bound to the enzyme forming a **flavoprotein**. It functions as a hydrogen acceptor in dehydrogenation reactions, being reduced to $FADH_2$. This in turn is oxidized to FAD by the *electron transport chain, thereby generating ATP (two molecules of ATP per molecule of $FADH_2$).

faeces Waste material that is eliminated from the alimentary canal through the *anus. Faeces consist of the indigestible residue of food that remains after the processes of digestion and absorption of nutrients and water have taken place, together with bacteria and dead cells shed from the gut lining.

Fahrenheit, Gabriel Daniel (1686–1736) German physicist, who became an instrument maker in Amsterdam. In 1714 he developed the mercury-in-glass thermometer, and devised a temperature scale to go with it (*see* FAHRENHEIT SCALE).

Fahrenheit scale A temperature scale in which (by modern definition) the temperature of boiling water is taken as 212 degrees and the temperature of melting ice as 32 degrees. It was invented in 1714 by Gabriel Fahrenheit, who set the zero at the lowest temperature he knew how to obtain in the laboratory (by mixing ice and common salt) and took his own body temperature as 96°F. The scale is no longer in scientific use. To convert to the *Celsius scale the formula is $C = 5(F - 32)/9$.

Fajans' method *See* ADSORPTION INDICATOR.

Fajans' rules Rules indicating the extent to which an ionic bond has covalent character caused by polarization of the ions. Covalent character is more likely if:
(1) the charge of the ions is high;
(2) the positive ion is small or the negative ion is large;
(3) the positive ion has an outer electron configuration that is not a noble-gas configuration.

The rules were introduced by the Polish–American chemist Kasimir Fajans (1887–1975).

fallopian tube (oviduct) The tube that carries egg cells from the *ovary to the womb in mammals. The eggs are carried by the action of muscles and cilia. It was named after Gabriel Fallopius.

Fallopius, Gabriel (1523–62) Italian anatomist, who was professor of anatomy at Pisa (from 1548) and Padua (from 1551). Best known for his discoveries about the human skeletal and reproductive systems, he identified the oviducts, which are named after him (*fallopian tubes).

fall-out **1. (radioactive fall-out)** Radioactive particles deposited from the atmosphere either from a nuclear explosion or from a nuclear accident. **Local fall-out**, within 250 km of an explosion, falls within a few hours of the explosion. **Tropospheric fall-out** consists of fine particles deposited all round the earth in the approximate latitude of the explosion within about one week. **Stratospheric fall-out** may fall anywhere on earth over a period of years. The most dangerous radioactive isotopes in fall-out are the fission fragments iodine–131 and strontium–90. Both can be taken up by grazing animals and passed on to human populations in milk, milk products, and meat. Iodine–131 accumulates in the thyroid gland and strontium–90 accumulates in bones. **2. (chemical fall-out)** Hazardous chemicals discharged into and subsequently released from the atmosphere, especially by factory chimneys.

false fruit *See* PSEUDOCARP.

family **1.** (in taxonomy) A category used in the *classification of organisms that consists of one or several similar or closely related genera. Similar families are grouped into an order. Family names end in *-aceae* or *-ae* in botany (e.g. Cactaceae) and *-idae* in zoology (e.g. Equidae). The names are usually derived from a type genus (*Cactus* and *Equus* in the examples above) that is characteristic of the whole family (*see* TYPE SPECIMEN). In botany, families are sometimes called **natural orders**. **2.** (in molecular biology) A group of proteins with shared similarities in their amino-acid sequence, and often similarities in function, due to evolutionary divergence from a putative common ancestral protein. For example, the various types and subtypes of *adrenoceptors can be considered as a protein family.

farad Symbol F. The SI unit of capacitance, being the capacitance of a capacitor that, if charged with one coulomb, has a potential difference of one volt between its plates. 1 F = 1 C V^{-1}. The farad is too large for most applications; the practical unit is the microfarad (10^{-6} F). The unit is named after Michael Faraday.

Faraday, Michael (1791–1867) British chemist and physicist, who received little formal education. He started to experiment on electricity and in 1812 attended lectures by Sir Humphry *Davy at the Royal Institution; a year later he became Davy's assistant. He remained at the Institution until 1861. Faraday's chemical discoveries include the liquefaction of chlorine (1823) and benzene (1825) as well as the laws of electrolysis (*see* FARADAY'S LAWS). He is probably best remembered for his work in physics: in 1821 he demonstrated electromagnetic rotation (the principle of the *electric motor) and discovered *electromagnetic induction (the principle of the dynamo). In 1845 he discovered the *Faraday effect.

Faraday cage An earthed screen made of metal wire that surrounds an electric device in order to shield it from external electrical fields.

Faraday constant Symbol *F*. The electric charge carried by one mole of electrons or singly ionized ions, i.e. the product of the *Avogadro constant and the charge on an electron (disregarding sign). It has the value $9.648\ 5309(29) \times 10^4$ coulombs per mole. This number of coulombs is sometimes treated as a unit of electric charge called the **faraday**.

Faraday disc *See* HOMOPOLAR GENERATOR.

Faraday effect The rotation of the plane of polarization of electromagnetic radiation

on passing through an isotropic medium exposed to a magnetic field. The angle of rotation is proportional to Bl, where l is the length of the path of the radiation in the medium and B is the magnetic flux density.

Faraday's laws Two laws describing electrolysis:
(1) The amount of chemical change during electrolysis is proportional to the charge passed.
(2) The charge required to deposit or liberate a mass m is given by $Q = Fmz/M$, where F is the Faraday constant, z the charge of the ion, and M the relative ionic mass.

These are the modern forms of the laws. Originally, they were stated by Faraday (1934) in a different form:
(1) The amount of chemical change produced is proportional to the quantity of electricity passed.
(2) The amount of chemical change produced in different substances by a fixed quantity of electricity is proportional to the electrochemical equivalent of the substance.

Faraday's laws of electromagnetic induction (1) An e.m.f. is induced in a conductor when the magnetic field surrounding it changes. (2) The magnitude of the e.m.f. is proportional to the rate of change of the field. (3) The sense of the induced e.m.f. depends on the direction of the rate of change of the field.

farming *See* AGRICULTURE.

fascia A sheet of fibrous connective tissue occurring beneath the skin and also enveloping glands, vessels, nerves, and forming muscle and tendon sheaths.

fascicle **1.** A small bundle of nerve or muscle fibres. **2.** *See* VASCULAR BUNDLE.

fast green A green dye used in optical microscopy that stains cellulose, cytoplasm, collagen, and mucus green. It is frequently used to stain plant tissues, with *safranin as a counterstain. Unlike **light green**, a similar dye, it does not fade easily.

fast-ion conductor (superionic conductor) A solid conductor of electricity in which the moving particles are ions, which transport electric charge by moving rapidly between vacancies in the lattice of a crystal. Substances of this type are sometimes called **solid electrolytes**. They are used in batteries and fuel cells.

fast neutron A neutron resulting from nuclear fission that has an energy in excess of 0.1 MeV (1.6×10^{-14} J), having lost little of its energy by collision. In some contexts **fast fission** is defined as fission brought about by fast neutrons, i.e. neutrons having energies in excess of 1.5 MeV (2.4×10^{-13} J), the fission threshold of uranium–238. *See also* NUCLEAR REACTOR; SLOW NEUTRON.

fast reactor *See* NUCLEAR REACTOR.

fat A mixture of lipids, chiefly *triglycerides, that is solid at normal body temperatures. Fats occur widely in plants and animals as a means of storing food energy, having twice the calorific value of carbohydrates. In mammals, fat is deposited in a layer beneath the skin (subcutaneous fat) and deep within the body as a specialized *adipose tissue (*see also* BROWN FAT). The insulating properties of fat are also important, especially in animals lacking fur and those inhabiting cold climates (e.g. seals and whales).

Fats derived from plants and fish generally have a greater proportion of unsaturated *fatty acids than those from mammals. Their melting points thus tend to be lower, causing a softer consistency at room temperatures. Highly unsaturated fats are liquid at room temperatures and are therefore more properly called *oils.

fat body **1.** An abdominal organ in amphibians attached to the anterior of each kidney. It contains a reserve of fat that nourishes the gonads during the winter hibernation in readiness for the spring breeding season. **2.** A mass of fatty tissue spreading throughout the body cavity of insects in which fats, proteins, and glycogen are stored as a reserve for hibernation or pupation.

fat cell Any of the cells of *adipose tissue, in which fats (triglycerides) are stored. Fat cells contain enzymes (lipases) that can break down fat into glycerol and fatty acids, which can be transported in the blood to the liver, where they are used in *fatty-acid oxidation.

fathom A unit used to describe a depth of water. It is equal to 6 feet (1.83 m).

fatigue **1.** A decline in the level of response of tissues (such as muscle), cells, etc., to nervous stimulation, which occurs after prolonged and continued stimulation of these structures. **2.** *See* METAL FATIGUE.

fatty acid An organic compound consist-

ing of a hydrocarbon chain and a terminal carboxyl group (*see* CARBOXYLIC ACIDS). Chain length ranges from one hydrogen atom (methanoic, or formic, acid, HCOOH) to nearly 30 carbon atoms. Ethanoic (acetic), propanoic (propionic), and butanoic (butyric) acids are important in metabolism. Long-chain fatty acids (more than 8–10 carbon atoms) most commonly occur as constituents of certain lipids, notably glycerides, phospholipids, sterols, and waxes, in which they are esterified with alcohols. These long-chain fatty acids generally have an even number of carbon atoms; unbranched chains predominate over branched chains. They may be **saturated** (e.g. *palmitic (hexadecanoic) acid and *stearic (octadecanoic) acid) or **unsaturated**, with one double bond (e.g. *oleic (cis-octodec-9-enoic) acid) or two or more double bonds, in which case they are called **polyunsaturated fatty acids** (e.g. *linoleic acid and *linolenic acid). *See also* ESSENTIAL FATTY ACIDS.

The physical properties of fatty acids are determined by chain length, degree of unsaturation, and chain branching. Short-chain acids are pungent liquids, soluble in water. As chain length increases, melting points are raised and water-solubility decreases. Unsaturation and chain branching tend to lower melting points.

fatty-acid oxidation (β-oxidation) The metabolic pathway in which fats are metabolized to release energy. Fatty-acid oxidation occurs continually but does not become a major source of energy until the animal's carbohydrate resources are exhausted, for example during starvation. Fatty-acid oxidation occurs chiefly in mitochondria in animal cells, and in *peroxisomes in plant cells. A series of reactions cleave off two carbon atoms at a time from the hydrocarbon chain of the fatty acid. These two-carbon fragments are combined with *coenzyme A to form *acetyl coenzyme A (acetyl CoA), which then enters the *Krebs cycle. The formation of acetyl CoA occurs repeatedly until all the hydrocarbon chain has been used up.

fault A fracture in the earth's crust along which there has been displacement of rock on one side relative to the other. The displacement ranges from a few centimetres to a few kilometres and may occur in a horizontal, oblique, or vertical direction. The extent of vertical displacement of the strata is the **throw**; the horizontal displacement is the **heave**. The side of the fault on which the strata have moved relatively downward is known as the downthrow side; the other is the upthrow side.

fauna All the animal life normally present in a given habitat at a given time. *See also* MACROFAUNA; MICROFAUNA. *Compare* FLORA.

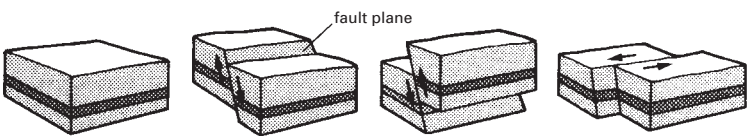
***f*-block elements** The block of elements in the *periodic table consisting of the lanthanoid series (from cerium to lutetium) and the actinoid series (from thorium to lawrencium). They are characterized by having two *s*-electrons in their outer shell (*n*) and *f*-electrons in their inner (*n*–1) shell.

f.c.c. Face-centred cubic. *See* CUBIC CRYSTAL.

F-centre *See* COLOUR CENTRE.

feathers The body covering of birds, formed as outgrowths of the epidermis and composed of the protein *keratin. Feathers provide heat insulation, they give the body its streamlined shape, and those of the wings and tail are important in flight. Basically a feather consists of a **quill**, which is embedded in the skin attached to a feather follicle and is continuous with the shaft (**rachis**) of the feather, which carries the *barbs. This basic structure is modified depending on the type of feather (*see* CONTOUR FEATHERS; DOWN FEATHERS; FILOPLUMES).

fecundity The number of offspring produced by an organism (in higher animals, generally the female of the species) in a given time. Normally all organisms, assum-



Faults.

ing they reach reproductive age, are sufficiently fecund to replace themselves several times over. Darwin noted this, together with the fact that population numbers nevertheless tended to remain fairly constant: these observations led him to formulate his theory of evolution by *natural selection. *Compare* FERTILITY.

feedback The use of part of the output of a system to control its performance. In **positive feedback**, the output is used to enhance the input; an example is an electronic oscillator, or the howl produced by a loudspeaker that is placed too close to a microphone in the same circuit. A small random noise picked up by the microphone is amplified and reproduced by the loudspeaker. The microphone now picks it up again; it is further amplified, and fed from the speaker to microphone once again. This continues until the system is overloaded. In **negative feedback**, the output is used to reduce the input. In electronic amplifiers, stability is achieved, and distortion reduced, by using a system in which the input is decremented in proportion as the output increases. A similar negative feedback is used in *governors that reduce the fuel supply to an engine as its speed increases.

Many biological processes rely on negative feedback. As the population of a species expands, so its food supply per individual is diminished; the result is that the population then begins to fall. Many biochemical processes are controlled by feedback *inhibition. Feedback mechanisms play an important role in maintaining a state of equilibrium within an organism (*see* HOMEOSTASIS).

feeding *See* INGESTION.

Fehling's test A chemical test to detect *reducing sugars and aldehydes in solution, devised by the German chemist Hermann von Fehling (1812–85). **Fehling's solution** consists of Fehlings A (copper(II) sulphate solution) and Fehling's B (alkaline 2,3-dihydroxybutanedioate (sodium tartrate) solution), equal amounts of which are added to the test solution. After boiling, a positive result is indicated by the formation of a brick-red precipitate of copper(I) oxide. Methanal, being a strong reducing agent, also produces copper metal; ketones do not react. The test is now little used, having been replaced by *Benedict's test.

feldspars A group of silicate minerals, the most abundant minerals in the earth's crust. They have a structure in which $(Si,Al)O_4$ tetrahedra are linked together with potassium, sodium, and calcium and very occasionally barium ions occupying the large spaces in the framework. The chemical composition of feldspars may be expressed as combinations of the four components:
anorthite (An), $CaAl_2Si_2O_8$;
albite (Ab), $NaAlSi_3O_8$;
orthoclase (Or), $KAlSi_3O_8$;
celsian (Ce), $BaAl_2Si_2O_8$.
The feldspars are subdivided into two groups: the **alkali feldspars** (including microcline, orthoclase, and sanidine), in which potassium is dominant with a smaller proportion of sodium and negligible calcium; and the **plagioclase feldspars**, which vary in composition in a series that ranges from pure sodium feldspar (albite) through to pure calcium feldspar (anorthite) with negligible potassium. Feldspars form colourless, white, or pink crystals with a hardness of 6 on the Mohs' scale.

feldspathoids A group of alkali aluminosilicate minerals that are similar in chemical composition to the *feldspars but are relatively deficient in silica and richer in alkalis. The structure consists of a framework of $(Si,Al)O_4$ tetrahedra with aluminium and silicon atoms at their centres. The feldspathoids occur chiefly with feldspars but do not coexist with free quartz (SiO_2) as they react with silica to yield feldspars. The chief varieties of feldspathoids are:
nepheline, $KNa_3(AlSiO_4)_4$;
leucite, $KAlSi_2O_6$;
analcime, $NaAlSi_2O_6.H_2O$;
cancrinite, $Na_8(AlSiO_4)_6(HCO_3)_2$;
and the sodalite subgroup comprising
sodalite, $3(NaAlSiO_4).NaCl$;
nosean, $3(NaAlSiO_4).Na_2SO_4$;
haüyne, $3(NaAlSiO_4).CaSO_4$;
lazurite $(Na,Ca)_8(Al,Si)_{12}O_{24}(S,SO_4)$ (*see* LAPIS LAZULI).

felsic (from *fel*dspar plus *sil*ica) Denoting any light-coloured silicate material or a rock in which such minerals predominate. Felsic minerals include feldspar, feldspathoids, and quartz. *See also* MAFIC.

FEM *See* FIELD-EMISSION MICROSCOPE.

female **1.** Denoting the gamete (sex cell) that, during *sexual reproduction, fuses with a *male gamete in the process of fertilization. Female gametes are generally larger than the male gametes and are usually im-

motile (*see* OOSPHERE; OVUM). **2.** (Denoting) an individual organism whose reproductive organs produce only female gametes. *Compare* HERMAPHRODITE.

femoral Of or relating to the thigh or the femur (thigh bone). For example, the **femoral artery** runs down the front of the thigh.

femto- Symbol f. A prefix used in the metric system to denote 10^{-15}. For example, 10^{-15} second = 1 femtosecond (fs).

femtochemistry The study of chemical reactions using lasers that produce very short-duration pulses of light (typically 10–100 femtoseconds, 10^{-14}–10^{-13} s). The pulses are produced using dye lasers or using solid-state lasers made from titanium-doped sapphire. Femtosecond lasers can be used to study the breaking and formation of individual chemical bonds in compounds.

femur **1.** The thigh bone of terrestrial vertebrates. It articulates at one end with the pelvic girdle at the hip joint and at the other (via two *condyles) with the *tibia. **2.** The third segment of an insect's leg, attached to the *trochanter. *See also* COXA.

fenestra Either of the two delicate membranes between the *middle ear and the *inner ear. The upper membrane is the **fenestra ovalis** (*see* OVAL WINDOW); the lower membrane is the **fenestra rotunda** (*see* ROUND WINDOW).

Fenton's reagent A mixture of hydrogen peroxide and iron(II) sulphate used to produce free radicals by reactions of the type

$$Fe^{2+} + H_2O_2 \rightarrow Fe^{3+} + \cdot OH + OH^-$$

$$Fe^{3+} + H_2O_2 \rightarrow Fe^{2+} + \cdot OOH + H^+$$

It is used in water treatment and as a reagent in organic synthesis to introduce an –OH group into an aromatic drug.

Fermat's principle The path taken by a ray of light between any two points in a system is always the path that takes the least time. This principle leads to the law of the rectilinear propagation of light and the laws of reflection and refraction. It was discovered by the French mathematician, Pierre de Fermat (1601–65).

fermentation A form of *anaerobic respiration occurring in certain microorganisms, e.g. yeasts. **Alcoholic fermentation** comprises a series of biochemical reactions by which pyruvate (the end product of *glycolysis) is converted to ethanol and carbon dioxide. Fermentation is the basis of the baking, wine, and beer industries.

fermi A unit of length formerly used in nuclear physics. It is equal to 10^{-15} metre. In SI units this is equal to 1 femtometre (fm). It was named after Enrico Fermi.

Fermi, Enrico (1901–54) Italian-born US physicist. He became a professor at Rome University, where in 1934 he discovered how to produce slow (thermal) neutrons. He used these to create new radioisotopes, for which he was awarded the 1938 Nobel Prize. In 1938 he and his Jewish wife emigrated to the USA. In 1942 he led the team that built the first atomic pile (nuclear reactor) in Chicago. Fermi was an influential theoretical physicist who, independently of Paul Dirac, discovered Fermi–Dirac statistics. He also proposed the first proper theory of weak interactions.

Fermi–Dirac statistics *See* QUANTUM STATISTICS.

Fermi level The energy in a solid at which the average number of particles per quantum state is ½; i.e. one half of the quantum states are occupied. The Fermi level in conductors lies in the conduction band (*see* ENERGY BANDS), in insulators it lies in the valence band, and in semiconductors it falls in the gap between the conduction band and the valence band. At absolute zero all the electrons would occupy energy levels up to the Fermi level and no higher levels would be occupied. It is named after Enrico Fermi.

fermion An *elementary particle (or bound state of an elementary particle, e.g. an atomic nucleus or an atom) with half-integral spin; i.e. a particle that conforms to Fermi–Dirac statistics (*see* QUANTUM STATISTICS). *Compare* BOSON.

fermium Symbol Fm. A radioactive metallic transuranic element belonging to the *actinoids; a.n. 100; mass number of the most stable isotope 257 (half-life 10 days). Ten isotopes are known. The element was first identified by Albert Ghiorso and associates in debris from the first hydrogen-bomb explosion in 1952.

SEE WEB LINKS

- Information from the WebElements site

ferns *See* FILICINOPHYTA.

ferrate An iron-containing anion, FeO_4^{2-}.

It exists only in strong alkaline solutions, in which it forms purple solutions.

Ferrel's law A law stating that a body moving across the surface of the earth will tend to be deflected to the right in the northern hemisphere and to the left in the southern hemisphere as a result of the earth's rotation. It was proposed in 1858 by the US meteorologist William Ferrel (1817–91).

ferric alum One of the *alums, $K_2SO_4.Fe_2(SO_4)_3.24H_2O$, in which the aluminium ion Al^{3+} is replaced by the iron(III) (ferric) ion Fe^{3+}.

ferric chloride test A *presumptive test for morphine. The reagent is a 10% solution of ferric chloride (iron(III) chloride, Fe Cl_3) in water. With morphine a blue-green coloration occurs, changing to green.

ferric compounds Compounds of iron in its +3 oxidation state; e.g. ferric chloride is iron(III) chloride, $FeCl_3$.

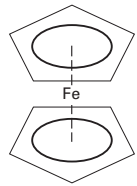
ferricyanide A compound containing the complex ion $[Fe(CN)_6]^{3-}$, i.e. the hexacyanoferrate(III) ion.

ferrimagnetism *See* MAGNETISM.

ferrite **1.** A member of a class of mixed oxides $MO.Fe_2O_3$, where M is a metal such as cobalt, manganese, nickel, or zinc. The ferrites are ceramic materials that show either ferrimagnetism or ferromagnetism, but are not electrical conductors. For this reason they are used in high-frequency circuits as magnetic cores. **2.** *See* STEEL.

ferroalloys Alloys of iron with other elements made by smelting mixtures of iron ore and the metal ore; e.g. ferrochromium, ferrovanadium, ferromanganese, ferrosilicon, etc. They are used in making alloy *steels.

ferrocene An orange-red crystalline solid, $Fe(C_5H_5)_2$; m.p. 173°C. It can be made by adding the ionic compound $Na^+C_5H_5^-$ (cyclopentadienyl sodium, made from sodium and cyclopentadiene) to iron(III) chloride. In ferrocene, the two rings are parallel, with the iron ion sandwiched between them (hence the name **sandwich compound**: see formula). The bonding is between pi orbitals on the rings and *d*-orbitals on the Fe^{2+} ion. The compound can undergo electrophilic substitution on the C_5H_5 rings (they have some aromatic character). It can also be oxidized to the blue ion $(C_5H_5)_2Fe^+$. Ferrocene is the first of a class of similar complexes called **metallocenes**. Its systematic name is **di-π-cyclopentadienyl iron(II)**.



Ferrocene.

ferrocyanide A compound containing the complex ion $[Fe(CN)_6]^{4-}$, i.e. the hexacyanoferrate(II) ion.

ferroelectric materials Ceramic dielectrics, such as Rochelle salt and barium titanate, that have a domain structure making them analogous to ferromagnetic materials (*see* MAGNETISM). They exhibit hysteresis and usually the *piezoelectric effect.

ferromagnetism *See* MAGNETISM.

ferrosoferric oxide *See* TRIIRON TETROXIDE.

ferrous compounds Compounds of iron in its +2 oxidation state; e.g. ferrous chloride is iron(II) chloride, $FeCl_2$.

fertile material A nuclide that can absorb a neutron to form a *fissile material. Uranium–238, for example, absorbs a neutron to form uranium–239, which decays to plutonium–239. This is the type of conversion that occurs in a breeder reactor (*see* NUCLEAR REACTOR).

fertility **1.** The potential capability of an organism to reproduce itself. In sexually reproducing plants and animals it is the number of fertilized eggs produced in a given time. For practical purposes this usually cannot be measured, and the only reliable indicators are the numbers of mature seeds produced, eggs laid, or live offspring delivered. However, these measures are strictly referred to as *fecundity, since they exclude fertilized embryos that have failed to develop. **2.** The relative ability of a soil to support plant growth. It consists of both physical factors, e.g. particle size and moisture content, and chemical factors, e.g. concentration and availability of nutrients.

fertilization (syngamy) The union of

male and female gametes (reproductive cells) during the process of sexual reproduction to form a **zygote**. It involves the fusion of the gametic nuclei (**karyogamy**) and cytoplasm (**plasmogamy**). As each gamete contains only half the correct number of chromosomes, fertilization and zygote formation results in a cell with the full complement of chromosomes, half of which are derived from each of the parents. In animals the process involves fusion of the nuclei of a spermatozoan and an ovum. In most aquatic animals (e.g. fish) this takes place in the surrounding water, into which the gametes are shed. Among most terrestrial animals (e.g. insects, many mammals) fertilization occurs in the body of the female, into which the sperms are introduced. In flowering plants, after *pollination, the male gamete (pollen) produces a *pollen tube, which grows down into the female reproductive organ (carpel) to enable a pollen nucleus to fuse with the egg nucleus.

In **self-fertilization** the male and female gametes are derived from the same individual. Among plants, self-fertilization (also called **autogamy**) is common in many cultivated species, e.g. wheat and oats. However, self-fertilization is a form of *inbreeding and does not allow for the mixing of genetic material; if it occurs over a number of generations it will result in offspring being less vigorous and productive than those resulting from cross-fertilization. In **cross-fertilization** (also called **allogamy** in plants) the gametes are derived from different individuals. In plants the pollen comes either from another flower of the same plant or from a different plant (*see also* INCOMPATIBILITY).

fertilizer Any substance that is added to soil in order to increase its productivity. Fertilizers can be of natural origin, such as *composts, or they can be made up of synthetic chemicals, particularly nitrates and phosphates. Synthetic fertilizers can increase crop yields dramatically, but when leached from the soil by rain, which runs into lakes, they also increase the process of eutrophication (*see* ALGAL BLOOM; EUTROPHIC). Bacteria that can fix nitrogen are sometimes added to the soil to increase its fertility; for example, in tropical countries the blue-green bacterium *Anabaena* is added to rice paddies to increase soil fertility.

FET *See* TRANSISTOR.

fetal membranes *See* EXTRAEMBRYONIC MEMBRANES.

fetus (foetus) The *embryo of a mammal, especially a human, when development has reached a stage at which the main features of the adult form are recognizable. In humans the embryo from eight weeks to birth is called a fetus.

Feulgen's test A histochemical test in which the distribution of DNA in the chromosomes of dividing cell nuclei can be observed. It was devised by the German chemist R. Feulgen (1884–1955). A tissue section is first treated with dilute hydrochloric acid to remove the purine bases of the DNA, thus exposing the aldehyde groups of the sugar deoxyribose. The section is then immersed in *Schiff's reagent, which combines with the aldehyde groups to form a magenta-coloured compound.

Feynman diagram *See* QUANTUM ELECTRODYNAMICS.

Fibonacci number Any number in the sequence 0, 1, 1, 2, 3, 5, 8, 13, 21,…, in which each term is the sum of the two preceding terms. The ratio of two consecutive terms tends to $\frac{1}{2}(1 + \sqrt{5})$, which is equal to the *golden ratio. It was named after the Italian mathematician Leonardo Fibonacci (*c.* 1170–1250).

fibre **1.** An elongated plant cell whose walls are extensively (usually completely) thickened with lignin. Fibres are found in the vascular tissue, usually in the xylem, where they provide structural support. The term is often used loosely to mean any kind of xylem element. The fibres of many species, e.g. flax, are of commercial importance. **2.** Any of various threadlike structures in the animal body, such as a muscle fibre, a nerve fibre, or a collagen fibre. **3. (dietary fibre; roughage)** The part of food that cannot be digested and absorbed to produce energy. Dietary fibre falls into four groups: **cellulose**, **hemicelluloses**, **lignins**, and **pectins**. Highly refined foods, such as sucrose, contain no dietary fibre. Foods with a high fibre content include wholemeal cereals and flour, root vegetables, nuts, and fruit. In human nutrition a distinction is made between soluble and insoluble fibre. **Soluble fibre** (e.g. in oats, pulses, fruit, vegetables) is broken down by bacteria in the large intestine to yield short-chain fatty acids, some of which can be absorbed and metabolized by the

liver. **Insoluble fibre** (e.g. in wholegrain cereals) is resistant to bacterial attack and forms a bulky water-retaining mass that promotes peristalsis and accelerates the passage of faeces. Dietary fibre is considered by some to be helpful in the prevention of many of the diseases of Western civilization, such as diverticulosis, constipation, appendicitis, obesity, and diabetes mellitus.

fibre optics The transmission of light along *optical fibres.

SEE WEB LINKS

- A comprehensive tutorial from Arc Electronics

fibrin The insoluble protein that forms fibres at the site of an injury and is the foundation of a blood clot. *See* BLOOD CLOTTING.

fibrinogen The protein dissolved in the blood plasma that, when suitably activated, is converted to insoluble *fibrin fibres. *See* BLOOD CLOTTING.

fibrinolysis The breakdown of the protein *fibrin by the enzyme *plasmin (**fibrinase** or **fibrinolysin**), which occurs when blood clots are removed from the circulation.

fibroblast A cell that secretes fibres in the intercellular substance of *connective tissue. The cells are long, flat, and star-shaped and lie close to collagen fibres. Fibroblasts are often grown in cell cultures.

fibrocartilage *See* CARTILAGE.

fibrous protein *See* PROTEIN.

fibula The smaller and outer of the two bones between the knee and the ankle in terrestrial vertebrates. *Compare* TIBIA.

Fick's law A law describing the diffusion that occurs when solutions of different concentrations come into contact, with molecules moving from regions of higher concentration to regions of lower concentration. Fick's law states that the rate of diffusion $\mathrm{d}n/\mathrm{d}t$, called the **diffusive flux** and denoted J, across an area A is given by: $\mathrm{d}n/\mathrm{d}t = J = -DA\partial c/\partial x$, where D is a constant called the **diffusion constant**, $\partial c/\partial x$ is the concentration gradient of the solute, and $\mathrm{d}n/\mathrm{d}t$ is the amount of solute crossing the area A per unit time. D is constant for a specific solute and solvent at a specific temperature. Fick's law was formulated by the German physiologist Adolf Eugen Fick (1829–1901) in 1855.

field A region in which a body experiences a *force as the result of the presence of some other body or bodies. A field is thus a method of representing the way in which bodies are able to influence each other. For example, a body that has mass is surrounded by a region in which another body that has mass experiences a force tending to draw the two bodies together. This is the gravitational field (*see* NEWTON'S LAW OF GRAVITATION). The other three *fundamental interactions can also be represented by means of fields of force. However in the case of the *magnetic field and *electric field that together create the electromagnetic interaction, the force can vary in direction according to the character of the field. For example, in the field surrounding a negatively charged body, a positively charged body will experience a force of attraction, while another negatively charged body is repelled.

The strength of any field can be described as the ratio of the force experienced by a small appropriate specimen to the relevant property of that specimen, e.g. force/mass for the gravitational field. *See also* QUANTUM FIELD THEORY.

field capacity The amount of water that remains in a soil when excess has drained away. It is held by capillary forces of the soil pores and reflects the physical nature of the soil.

field coil The coil in an electrical machine that produces the magnetic field.

field-effect transistor (FET) *See* TRANSISTOR.

field-emission microscope (FEM) A type of electron microscope in which a high negative voltage is applied to a metal tip placed in an evacuated vessel some distance from a glass screen with a fluorescent coating. The tip produces electrons by **field emission**, i.e. the emission of electrons from an unheated sharp metal part as a result of a high electric field. The emitted electrons form an enlarged pattern on the fluorescent screen, related to the individual exposed planes of atoms. As the resolution of the instrument is limited by the vibrations of the metal atoms, it is helpful to cool the tip in liquid helium. Although the individual atoms forming the point are not displayed, individual adsorbed atoms of other substances can be, and their activity is observable.

field-ionization microscope (field-ion microscope; FIM) A type of electron microscope that is similar in principle to the *field-

emission microscope, except that a high positive voltage is applied to the metal tip, which is surrounded by low-pressure gas (usually helium) rather than a vacuum. The image is formed in this case by **field ionization**: ionization at the surface of an unheated solid as a result of a strong electric field creating positive ions by electron transfer from surrounding atoms or molecules. The image is formed by ions striking the fluorescent screen. Individual atoms on the surface of the tip can be resolved and, in certain cases, adsorbed atoms may be detected.

field lens The lens in the compound eyepiece of an optical instrument that is furthest from the eye. Its function is to increase the field of view by refracting towards the main eye lens rays that would otherwise miss it.

field magnet The magnet that provides the magnetic field in an electrical machine. In some small dynamos and motors it is a permanent magnet but in most machines it is an electromagnet.

filament **1.** (in zoology) A long slender hairlike structure, such as any of the *barbs of a bird's feather. **2.** (in botany) The stalk of the *stamen in a flower. It bears the anther and consists mainly of conducting tissue. **3.** (in cell biology) Any of the microscopic protein fibres that form part of the *cytoskeleton. They include intermediate filaments and microfilaments (*see* ACTIN). **4.** (in physics) A thin wire, often of tungsten, that is heated by an electric current to incandescence, in light bulbs and thermionic valves.

file A collection of data stored in a computer. It may consist of program instructions or numerical, textual, or graphical information. It usually consists of a set of similar or related records.

file transfer protocol *See* FTP.

Filicinophyta (Pterophyta) A phylum of mainly terrestrial vascular plants (*see* TRACHEOPHYTE) – the ferns. Ferns are perennial plants bearing large conspicuous leaves (**fronds**: *see* MEGAPHYLL) usually arising from either a rhizome or a short erect stem. Bracken is a common example. Only the tree ferns have stems that reach an appreciable height. There is a characteristic uncurling of the young leaves as they expand into the adult form. Reproduction is by means of spores borne on the underside of specialized leaves (*sporophylls).

filler A solid inert material added to a synthetic resin or rubber, either to change its physical properties or simply to dilute it for economy.

film badge A lapel badge containing masked photographic film worn by personnel who could be exposed to ionizing radiation. The film is developed to indicate the extent that the wearer has been exposed to harmful radiation. Typically, the badges contain a number of filters of different materials and thickness, thus allowing an estimation of the type of radiation received.

filoplumes Minute hairlike *feathers consisting of a shaft (**rachis**) bearing a few unattached barbs. They are found between the contour feathers.

filter **1.** (in chemistry) A device for separating solid particles from a liquid or gas. The simplest laboratory filter for liquids is a funnel in which a cone of paper (**filter paper**) is placed. Special containers with a porous base of sintered glass are also used. *See also* GOOCH CRUCIBLE. **2.** (in physics) A device placed in the path of a beam of radiation to alter its frequency distribution. For example, a plane pigmented piece of glass may be placed over a camera lens to alter the relative intensity of the component wavelengths of the beam entering the camera. **3.** (in electronics) An electrical network that transmits signals within a certain frequency range but attenuates other frequencies.

filter feeding A method of feeding in which tiny food particles are strained from the surrounding water by various mechanisms. It is used by many aquatic invertebrates, especially members of the plankton, and by some vertebrates, notably baleen whales. *See also* CILIARY FEEDING; WHALEBONE.

filter pump A simple laboratory vacuum pump in which air is removed from a system by a jet of water forced through a narrow nozzle. The lowest pressure possible is the vapour pressure of water.

filtrate The clear liquid obtained by filtration.

filtration The process of separating solid particles using a filter. In **vacuum filtration**, the liquid is drawn through the filter by a vacuum pump. *Ultrafiltration is filtration

under pressure; for example, ultrafiltration of the blood occurs in the *nephrons of the vertebrate kidney.

FIM *See* FIELD-IONIZATION MICROSCOPE.

finder A small low-powered astronomical telescope, with a wide field of view, that is fixed to a large astronomical telescope so that the large telescope can be pointed in the correct direction to observe a particular celestial body.

fine chemicals Chemicals produced industrially in relatively small quantities and with a high purity; e.g. dyes and drugs.

fineness of gold A measure of the purity of a gold alloy, defined as the parts of gold in 1000 parts of the alloy by mass. Gold with a fineness of 750 contains 75% gold, i.e. 18 *carat gold.

fine structure Closely spaced optical spectral lines arising from *transitions between energy levels that are split by the vibrational or rotational motion of a molecule or by electron spin. They are visible only at high resolution. **Hyperfine structure**, visible only at very high resolution, results from the influence of the atomic nucleus on the allowed energy levels of the atom.

fine structure constant Symbol α. The dimensionless constant, with a value of about 1/137, that characterizes quantum electrodynamics. It is given by $\alpha = e^2/\hbar c$, where e is the charge on an electron, $\hbar$ is the Dirac constant, and c is the speed of light in free space.

finite series *See* SERIES.

fins The locomotory organs of aquatic vertebrates. In fish there are typically one or more **dorsal** and **ventral fins** (sometimes continuous), whose function is balance; a **caudal fin** around the tail, which is the main propulsive organ; and two paired fins: the **pectoral fins** attached to the pectoral (shoulder) girdle and the **pelvic fins** attached to the pelvic (hip) girdle, which are used in steering. These paired fins are homologous with the limbs of tetrapods. Fins are strengthened by a number of flexible fin rays, which may be cartilaginous, bony and jointed, horny, or fibrous and jointed.

firedamp Methane formed in coal mines.

first convoluted tubule *See* PROXIMAL CONVOLUTED TUBULE.

first-order reaction *See* ORDER.

Fischer–Tropsch process An industrial method of making hydrocarbon fuels from carbon monoxide and hydrogen. The process was invented in 1933 and used by Germany in World War II to produce motor fuel. Hydrogen and carbon monoxide are mixed in the ratio 2:1 (water gas was used with added hydrogen) and passed at 200°C over a nickel or cobalt catalyst. The resulting hydrocarbon mixture can be separated into a higher-boiling fraction for Diesel engines and a lower-boiling gasoline fraction. The gasoline fraction contains a high proportion of straight-chain hydrocarbons and has to be reformed for use in motor fuel. Alcohols, aldehydes, and ketones are also present. The process is also used in the manufacture of SNG from coal. It is named after the German chemist Franz Fischer (1852–1932) and the Czech Hans Tropsch (1839–1935).

fish *See* CHONDRICHTHYES (cartilaginous fish); OSTEICHTHYES (bony fish); PISCES.

FISH *See* FLUORESCENCE IN SITU HYBRIDIZATION.

fissile material A nuclide of an element that undergoes nuclear fission, either spontaneously or when irradiated by neutrons. Fissile nuclides, such as uranium–235 and plutonium–239, are used in *nuclear reactors and nuclear weapons. *Compare* FERTILE MATERIAL.

fission **1.** (in biology) A type of asexual reproduction occurring in some unicellular organisms, e.g. diatoms, protozoans, and bacteria, in which the parent cell divides to form two (**binary fission**) or more (**multiple fission**) similar daughter cells. **2.** (in physics) *See* NUCLEAR FISSION.

fission products *See* NUCLEAR FISSION.

fission-track dating A method of estimating the age of glass and other mineral objects by observing the tracks made in them by the fission fragments of the uranium nuclei that they contain. By irradiating the objects with neutrons to induce fission and comparing the density and number of the tracks before and after irradiation it is possible to estimate the time that has elapsed since the object solidified.

fitness (in genetics) A measure of the relative breeding success of an individual in a given population in a given time. The fittest individuals are those that contribute the

most offspring to the next generation. Fitness therefore reflects how well an organism is adapted to its environment, which determines its survival. *See also* INCLUSIVE FITNESS.

Fittig reaction *See* WURTZ REACTION.

Fitzgerald contraction *See* LORENTZ–FITZGERALD CONTRACTION.

fixation **1.** The first stage in the preparation of a specimen for microscopical examination, in which the tissue is killed and preserved in as natural a state as possible by immersion in a chemical **fixative**. The fixative prevents the distortion of cell components by denaturing its constituent protein. Some commonly used fixatives are formaldehyde, ethanol, and Bouin's fluid (for light microscopy), and osmium tetroxide and gluteraldehyde (for electron microscopy). Fixation may also be brought about by heat. **2.** *See* NITROGEN FIXATION.

fixed action pattern *See* INSTINCT.

fixed point A temperature that can be accurately reproduced to enable it to be used as the basis of a *temperature scale.

fixed star Any of the innumerable heavenly bodies that do not appear to alter their position on the *celestial sphere. They were so called by the ancients to distinguish them from the planets, which were once known as **wandering stars** because they appeared to move relative to the background of fixed stars. The discovery of the *proper motion of stars in the 18th century established that stars are not fixed in the sky although, because of their immense distances from the solar system, they may appear to be so.

Fizeau, Armand Hippolyte Louis (1819–96) French physicist. In 1845 he and Léon Foucault (1819–68) took the first photographs of the sun. In 1849 he measured the speed of light (*see* FIZEAU'S METHOD); he also analysed the *Doppler effect for light.

Fizeau's method A method of measuring the speed of light, invented by Armand Fizeau in 1849. A cogwheel rotating at high speed enables a series of flashes to be transmitted to a distant mirror. The light reflected back to the cogwheel is observed and the speed of light calculated from the rates of rotation of the wheel required to produce an eclipse of the returning light.

flaccid (in botany) Describing plant tissue that has become soft and less rigid than normal because the cytoplasm within its cells has shrunk and contracted away from the cell walls through loss of water (*see* PLASMOLYSIS).

flagellum (*pl.* **flagella**) **1.** (in prokaryotes) A long slender threadlike structure that protrudes from the cell surface of a bacterium. It rotates from its base and propels the bacterium along. Up to several micrometres in length, a flagellum is constructed of numerous subunits of the protein flagellin. **2.** (in eukaryotes) *See* UNDULIPODIUM.

flame A hot luminous mixture of gases undergoing combustion. The chemical reactions in a flame are mainly free-radical chain reactions and the light comes from fluorescence of excited molecules or ions or from incandescence of small solid particles (e.g. carbon).

flame test A simple test for metals, in which a small amount of the sample (usually moistened with hydrochloric acid) is placed on the end of a platinum wire and held in a Bunsen flame. Certain metals can be detected by the colour produced: barium (green), calcium (brick red), lithium (crimson), potassium (lilac), sodium (yellow), strontium (red).

flare star A type of cool *red dwarf whose brightness changes unpredictably and rapidly, probably because of the release of intense amounts of energy brought about by magnetic fields in the star's photosphere. The high-energy flares make the red star appear much brighter, though often for only a few minutes. *See also* SOLAR FLARE.

flash memory A form of storage in which the data may be altered electrically. The device does not need refreshing to maintain the data, which is stored even when power is removed. Flash memory finds application in computers, in digital cameras, and in portable storage devices that emulate hard disks (e.g. *USB drives).

flash photolysis A technique for studying free-radical reactions in gases. The apparatus used typically consists of a long glass or quartz tube holding the gas, with a lamp outside the tube suitable for producing an intense flash of light. This dissociates molecules in the sample creating free radicals, which can be detected spectroscopically by a beam of light passed down the axis of the tube. It is possible to focus the spec-

trometer on an absorption line for a particular product and measure its change in intensity with time using an oscilloscope. In this way the kinetics of very fast free-radical gas reactions can be studied.

flash point The temperature at which the vapour above a volatile liquid forms a combustible mixture with air. At the flash point the application of a naked flame gives a momentary flash rather than sustained combustion, for which the temperature is too low.

flatworms *See* PLATYHELMINTHES.

flavin adenine dinucleotide *See* FAD.

flavones A group of *flavonoid compounds found in many plants.

flavonoid One of a group of naturally occurring phenolic compounds many of which are plant pigments. They include the *anthocyanins, **flavonols**, and **flavones**. Plant-derived flavonoids in foods are strong antioxidants in their natural state but are poorly absorbed from the intestine and rapidly metabolized and excreted. However, they might be beneficial to health by stimulating the body to produce enzymes that help to eliminate mutagens and carcinogens.

flavoprotein *See* FAD.

flavour *See* ELEMENTARY PARTICLES.

fleas *See* SIPHONAPTERA.

Fleming, Sir Alexander (1881–1955) British bacteriologist, born in Scotland. He studied medicine at St Mary's Hospital, London, where he remained all his life. In 1922 he identified *lysozyme, an enzyme that destroys bacteria, and in 1928 discovered the antibiotic *penicillin. He shared the 1945 Nobel Prize for physiology or medicine with *Florey and *Chain, who first isolated the drug.

Fleming's rules Rules to assist in remembering the relative directions of the field, current, and force in electrical machines. The left hand refers to motors, the right hand to generators. If the forefinger, second finger, and thumb of the left hand are extended at right angles to each other, the forefinger indicates the direction of the field, the second finger the direction of the current, and the thumb the direction of the force. If the right hand is used the digits indicate these directions in a generator. The mnemonic was invented by Sir John Ambrose Fleming (1849–1945).

flexor A muscle that causes a limb to bend by bringing the two parts of the limb together. An example is the *biceps. Flexors work antagonistically with *extensors. *See* VOLUNTARY MUSCLE.

flies *See* DIPTERA.

flight **1.** Any form of *locomotion in air, which can be active or passive (**gliding**). Mechanisms of flight have evolved mainly in birds, bats, and insects: these animals are adapted for flight by the presence of **wings**, which increases the ratio of surface area to body weight. Birds possess powerful flight muscles: the **depressor** muscle runs from the underside of the humerus to the sternum and is responsible for the downstroke of the wing; the **levator** muscle works antagonistically, producing the upstroke. Flight in insects works in a similar fashion but the muscles that control the wing movement are attached to the thorax. A few species of mammals, reptiles, and fish have developed flight to a lesser extent. For example, flying squirrels (order Dermoptera) possess a membrane attached to the limbs that can open and function as a parachute, allowing the animals to glide. **2.** Part of a survival mechanism in an animal that is generated in response to a threatening situation. A potentially dangerous situation can induce the release of *adrenaline, which prepares the animal for 'fight or flight' by increasing the blood pressure and heart rate and diverting the blood flow to the muscles and heart. **3.** *See* AERODYNAMICS.

flint (chert) Very hard dense nodules of microcrystalline quartz and chalcedony found in chalk and limestone.

flip-flop (bistable circuit) An electronic circuit that has two stable states. It is switched from one stable state to the other by means of a triggering pulse. They are extensively used as *logic circuits in computers.

flocculation The process in which particles in a colloid aggregate into larger clumps. Often, the term is used for a reversible aggregation of particles in which the forces holding the particles together are weak and the colloid can be redispersed by agitation. The stability of a lyophobic colloidal dispersion depends on the existence of a layer of electric charge on the surface of the particles. Around this are attracted electrolyte ions of opposite charge, which form a mobile ionic

'atmosphere'. The result is an electrical double layer on the particle, consisting of an inner shell of fixed charges with an outer mobile atmosphere. The potential energy between two particles depends on a repulsive interaction between double layers on adjacent particles and an attractive interaction due to *van der Waals' forces between the particles.

At large separations, the repulsive forces dominate, and this accounts for the overall stability of the colloid. As the particles become closer together, the potential energy increases to a maximum and then falls sharply at very close separations, where the van der Waals forces dominate. This potential-energy minimum corresponds to *coagulation and is irreversible. If the *ionic strength of the solution is high, the ionic atmosphere around the particles is dense and the potential-energy curve shows a shallow minimum at larger separation of particles. This corresponds to flocculation of the particles. Ions with a high charge are particularly effective for causing flocculation and coagulation.

flocculent Aggregated in woolly masses; used to describe precipitates.

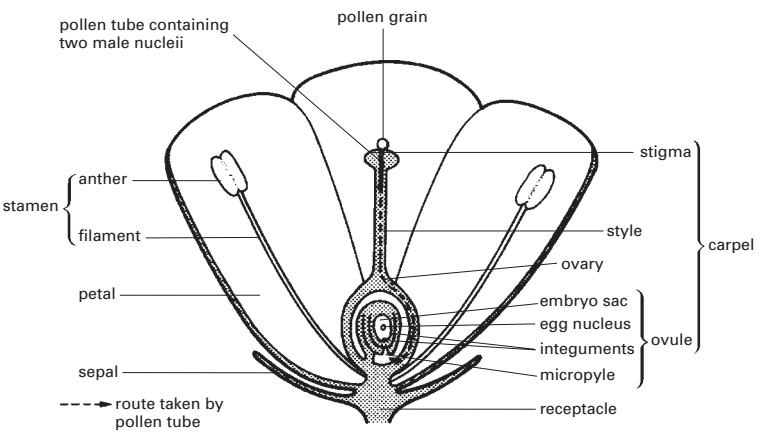
floppy disk (diskette) A flexible plastic disk with a magnetic coating encased in a stiff envelope. It is used to store information in a small computer system. *See* MAGNETIC DISK.

flora All the plant life normally present in a given habitat at a given time. *See also* MICROFLORA. *Compare* FAUNA.

Florey, Howard Walter, Baron (1898–1968) Australian pathologist, who moved to Oxford in 1922. After working in Cambridge and Sheffield (studying *lysozyme), he returned to Oxford in 1935. There he teamed up with Ernst *Chain and by 1939 they succeeded in isolating and purifying *penicillin. They also developed a method of producing the drug in large quantities and carried out its first clinical trials. The two men shared the 1945 Nobel Prize for physiology or medicine with penicillin's discoverer, Alexander *Fleming.

florigen A hypothetical plant growth substance that is postulated to transmit the stimulus for flowering, which is a response to photoperiod (*see* PHOTOPERIODISM), from the leaves to the apex of the plant. However, florigen has never been isolated and some plant physiologists question its existence.

flower The structure in angiosperms (flowering plants) that bears the organs for sexual reproduction. Flowers are very variable in form, ranging from the small green insignificant wind-pollinated flowers of many grasses to spectacular brightly coloured insect-pollinated flowers. Flowers are often grouped together into *inflorescences, some of which (e.g. that of dandelion) are so compacted as to resemble a single flower. Typically flowers consist of a receptacle that bears sepals, petals, stamens,



Flower. Section through a monocarpellary flower at the time of pollination.

and carpels (see illustration). The flower parts are adapted to bring about pollination and fertilization resulting in the formation of seeds and fruits. The sepals are usually green and leaflike and protect the flower bud. The petals of insect-pollinated flowers are adapted in many ingenious ways to attract insects and, in some instances, other animals. For example, some flowers are adapted to attract short-tongued insects by having an open shallow *corolla tube and nectar situated in an exposed position. Flowers adapted for pollination by long-tongued insects have a long corolla tube of fused petals with nectar in a concealed position. The tongue of the insect brushes against the anthers and stigma before reaching the nectar. Wind-pollinated flowers, in contrast, are inconspicuous. The anthers dangle outside the corolla and the stigmas have a feathery surface to catch the pollen grains.

Some species are adapted for self-pollination and have small flowers, no nectar, and stamens and carpels that mature simultaneously.

flowering plants *See* ANTHOPHYTA.

fluctuations Random deviations in the value of a quantity about some average value. In all systems described by *quantum mechanics fluctuations, called **quantum fluctuations**, occur – even at the *absolute zero of thermodynamic temperature as a result, ultimately, of the Heisenberg *uncertainty principle. In any system above absolute zero, fluctuations, called **thermal fluctuations**, occur. It is necessary to take fluctuations into account to obtain a quantitative theory of *phase transitions in three dimensions. The formation of structure in the *early universe is thought to be a result of quantum fluctuations.

fluidics The use of jets of fluid in pipes to perform many of the control functions usually performed by electronic devices. Being about one million times slower than electronic devices, fluidic systems are useful where delay lines are required. They are also less sensitive to high temperatures, strong magnetic fields, and ionizing radiation than electronic devices.

fluidization A technique used in some industrial processes in which solid particles suspended in a stream of gas are treated as if they were in the liquid state. Fluidization is useful for transporting powders, such as coal dust. **Fluidized beds**, in which solid particles are suspended in an upward stream, are extensively used in the chemical industry, particularly in catalytic reactions where the powdered catalyst has a high surface area. They are also used in furnaces, being formed by burning coal in a hot turbulent bed of sand or ash through which air is passed. The bed behaves like a fluid, enabling the combustion temperature to be reduced so that the production of polluting oxides of nitrogen is diminished. By adding limestone to the bed with the fuel, the emission of sulphur dioxide is reduced.

High-pressure fluidized beds are also used in power-station furnaces in a **combined cycle** in which the products of combustion from the fluidized bed are used to drive a gas turbine, while a steam-tube boiler in the fluid bed raises steam to drive a steam turbine. This system both increases the efficiency of the combustion process and reduces pollution.

fluid mechanics The study of fluids at rest and in motion. **Fluid statics** is concerned with the pressures and forces exerted on liquids and gases at rest. *Hydrostatics is specifically concerned with the behaviour of liquids at rest. In **fluid dynamics** the forces exerted on fluids, and the motion that results from these forces, are examined. It can be divided into *hydrodynamics: the motion of liquids (not only water); and aerodynamics: the motion of gases.

Fluid dynamics is an important science used to solve many of the problems arising in aeronautical, chemical, mechanical, and civil engineering. It also enables many natural phenomena, such as the flight of birds, the swimming of fish, and the development of weather conditions, to be studied scientifically.

flukes *See* TREMATODA.

flunitrazepam A *benzodiazepine used medically in some countries as a powerful hypnotic, sedative, and muscle relaxant. It was marketed in the US under the tradename **Rohypnol**. Flunitrazepam has become notorious as a so-called 'date rape' drug. It is quickly eliminated from the body, difficult to detect, and causes amnesia, so that victims cannot remember events that occur when under the influence of the drug.

fluorescein A yellowish-red dye that produces yellow solutions with a green fluorescence. It is used in tracing water flow and as

an absorption indicator (*see* ADSORPTION INDICATOR).

fluorescence *See* LUMINESCENCE.

fluorescence in situ hybridization (FISH) A technique in which a DNA probe, labelled with a fluorescent dye, base-pairs (hybridizes) with the complementary base sequence of a target nucleotide. It is used in genetic mapping for locating specific genes within a chromosome set. Another application is for locating particular messenger RNAs (mRNAs) within cells.

fluorescent light *See* ELECTRIC LIGHTING.

fluoridation The process of adding very small amounts of fluorine salts (e.g. sodium fluoride, NaF) to drinking water to prevent tooth decay. The fluoride becomes incorporated into the fluoroapatite (*see* APATITE) of the growing teeth and reduces the incidence of *dental caries.

fluoride *See* HALIDE.

fluorination A chemical reaction in which a fluorine atom is introduced into a molecule. *See* HALOGENATION.

fluorine Symbol F. A poisonous pale yellow gaseous element belonging to group 17 (formerly VIIB) of the periodic table (the *halogens); a.n. 9; r.a.m. 18.9984; d. 1.7 g dm^{-3}; m.p. –219.62°C; b.p. –188.1°C. The main mineral sources are *fluorite (CaF_2) and *cryolite (Na_3AlF). The element is obtained by electrolysis of a molten mixture of potassium fluoride and hydrogen fluoride. It is used in the synthesis of organic fluorine compounds. Chemically, it is the most reactive and electronegative of all elements. It is a highly dangerous element, causing severe chemical burns on contact with the skin. The element was identified by Scheele in 1771 and first isolated by Moissan in 1886.

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fluorite (fluorspar) A mineral form of calcium fluoride, CaF_2, crystallizing in the cubic system. It is variable in colour; the most common fluorites are green and purple (blue john), but other forms are white, yellow, or brown. Fluorite is used chiefly as a flux material in the smelting of iron and steel; it is also used as a source of fluorine and hydrofluoric acid and in the ceramic and optical-glass industries.

fluorite structure *See* CALCIUM FLUORIDE.

fluorocarbons Compounds obtained by replacing the hydrogen atoms of hydrocarbons by fluorine atoms. Their inertness and high stability to temperature make them suitable for a variety of uses as oils, polymers, etc. *See also* CHLOROFLUOROCARBON; HALON.

5-fluorouracil (5-FU) A fluorine derivative of the pyrimidine uracil. It is used in chemotherapy where it inhibits the cell's ability to synthesize DNA. It is often used in a treatment regime along with cisplatin.

flux **1.** A substance applied to the surfaces of metals to be soldered to inhibit oxidation. **2.** A substance used in the smelting of metals to assist in the removal of impurities as slag. **3.** The number of particles flowing per unit area of cross section in a beam of particles. **4.** *See* LUMINOUS FLUX. **5.** *See* MAGNETIC FLUX. **6.** *See* ELECTRIC FLUX.

flux density **1.** *See* MAGNETIC FIELD. **2.** *See* ELECTRIC DISPLACEMENT.

fluxional molecule A molecule that undergoes alternate very rapid rearrangements of its atoms and thus only has a specific structure for a very short period of time. For example, the molecule ClF_3 has a T-shape at low temperatures (–60°C); at room temperature the fluorine atoms change position very rapidly and appear to have identical positions.

fluxmeter An instrument used to measure *magnetic flux. It is used in conjunction with a coil (the **search coil**) and resembles a moving-coil galvanometer except that there are no restoring springs. A change in the magnetic flux induces a momentary current in the search coil and in the coil of the meter, which turns in proportion and stays in the deflected position. This type of instrument has been largely superseded by a type using the Hall probe (*see* HALL EFFECT).

flyby A close approach made by a spacecraft to a planet, satellite, or asteroid without entering orbit or landing, mainly for the purpose of taking photographs or collecting data but also for carrying out a manoeuvre called a gravity assist, by which the spacecraft takes up a tiny fraction of a planet's rotational energy in order to change direction or boost its velocity.

FM (frequency modulation) *See* MODULATION.

fMRI Functional magnetic resonance imaging. *See* NUCLEAR MAGNETIC RESONANCE.

f-number *See* APERTURE.

foam A dispersion of bubbles in a liquid. Foams can be stabilized by *surfactants. Solid foams (e.g. expanded polystyrene or foam rubber) are made by foaming the liquid and allowing it to set. *See also* COLLOIDS.

foaming agent (blowing agent) A substance used to produce a liquid or solid foam (e.g. an expanded plastic). Physical agents are compressed gases; chemical foaming agents are substances that release gas under certain conditions (e.g. sodium hydrogencarbonate).

focal length The distance between the *optical centre of a lens or pole of a spherical mirror and its *principal focus.

focal point *See* FOCUS.

focal ratio *See* APERTURE.

Fock degeneracy A 'hidden' degeneracy that occurs in the spectrum of the hydrogen atom as a result of the rotational invariance in four dimensions associated with the Coulomb interation between the proton and the electron. It was discovered by the Soviet physicist Vladimir Fock (1898–1974) in 1935.

focus **1.** (in optics) Any point in an optical system through or towards which rays of light are converged. It is sometimes called the **focal point** and sometimes loosely used to mean *principal focus or (particularly by photographers) *focal length. **2.** (in mathematics) *See* CONIC; ELLIPSE.

focusing (in animal physiology) The process of directing and concentrating light from a source onto the *retina of the eye, by means of the lens, in order to obtain a clear image of objects at a range of distances. *See* ACCOMMODATION.

foetus *See* FETUS.

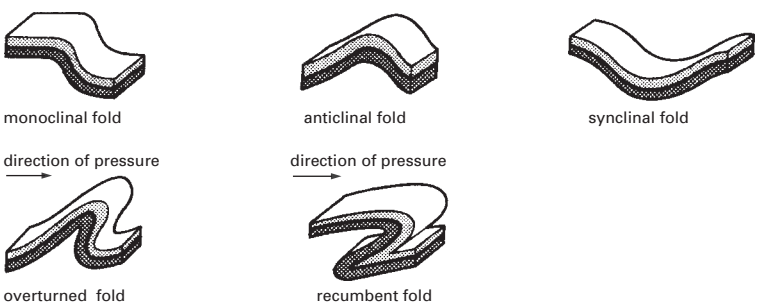
folacin *See* FOLIC ACID.

fold A wavelike form in layered sedimentary rock strata that results from deformational processes in the earth's crust. Basin-shaped folds in which the beds of rock dip towards each other are known as **synclines**; those in which the beds of rock are folded into an arch shape are known as **anticlines**. More complex folds result where the rock strata are subjected to intense horizontal pressures. See illustration.

folic acid (folacin) A vitamin of the *vitamin B complex. In its active form, tetrahydrofolic acid, it is a *coenzyme in various reactions involved in the metabolism of amino acids, purines, and pyrimidines. It is synthesized by intestinal bacteria and is especially abundant in green leafy vegetables. Deficiency causes poor growth and nutritional anaemia.

follicle **1.** (in animal anatomy) Any enclosing cluster of cells that protects and nourishes a cell or structure within. For example, follicles in the *ovary contain developing egg cells, while *hair follicles envelop the roots of hairs. **2.** (in botany) A dry fruit that, when ripe, splits along one side to release its seeds. It is formed from a single carpel containing one or more seeds. Follicles do not occur singly but are grouped to form clusters (**etaerios**). Examples include larkspur, columbine, and monk's hood.

follicle-stimulating hormone (FSH) A hormone, secreted by the anterior pituitary gland in mammals, that stimulates, in fe-



Folds.

male mammals, ripening of specialized structures in the ovary (*Graafian follicles) that produce ova and, in males, the formation of sperm in the testis. It is a major constituent of fertility drugs, used to treat failure of ovulation and decreased sperm production. *See also* GONADOTROPHIN.

food Any material containing *nutrients, such as carbohydrates, proteins and fats, which are required by living organisms in order to obtain energy for growth and maintenance. Heterotrophic organisms, such as animals, ingest their food (*see also* DIET); autotrophic organisms, such as plants, manufacture their food materials.

food chain The transfer of energy from green plants (the primary producers) through a sequence of organisms in which each eats the one below it in the chain and is eaten by the one above. Thus plants are eaten by herbivores, which are then eaten by carnivores. These may in turn be eaten by different carnivores. The position an organism occupies in a food chain is known as its *trophic level. In practice, many animals feed at several different trophic levels, resulting in a more complex set of feeding relationships known as a *food web. *See* BIOENERGETICS; CONSUMER; PRODUCER; PYRAMID OF BIOMASS; PYRAMID OF ENERGY; PYRAMID OF NUMBERS.

food poisoning An acute illness caused by food that may be naturally poisonous or contaminated by certain types of pathogenic microorganisms. The most common type of food poisoning in the UK is that caused by the bacteria belonging to the genus **Salmonella*, which inhabit the alimentary canal of livestock. Freezing and other types of *food preservation can prevent the growth of the bacteria and thorough cooking will kill the microorganisms before the meat is eaten. However, food poisoning can result if frozen meat is not completely thawed at its centre before cooking, as it may not reach sufficiently high temperatures to kill the bacteria during cooking. Another type of food poisoning, known as **botulism**, is caused by toxins produced by the bacterium *Clostridium botulinum*, which can grow in badly preserved canned foods. Other bacteria causing food poisoning include *Staphylococcus aureus, Campylobacter jejuni, *Listeria monocytogenes,* and pathogenic **Escherichia coli.*

food preservation Prevention of the spoilage of food, which is achieved by a variety of techniques. These aim to prevent bacterial and fungal decay and contamination of food, which can cause *food poisoning. For example, dehydration removes the water from food, which prevents microorganisms from growing. Treating food with salt (salting) causes the microorganisms to lose water due to osmosis. Pickling involves treatment with vinegar (ethanoic acid), which reduces the pH and prevents bacteria from growing. Heating food (**blanching**) to temperatures of 90°C denatures the enzymes that cause the breakdown of food and kills many bacteria. The food is then packed in air-tight containers, such as cans or bottles. Heating milk to high temperatures to kill the bacteria is the basis of *pasteurization. Freezing food prevents the growth of bacteria but does not necessarily kill them; thorough cooking is therefore essential. In *freeze drying, food is rapidly frozen and then dehydrated, usually in a vacuum. Prepreprared food can be preserved by the addition of chemicals (**food additives**), such as *sodium benzenecarboxylate, proprionates, and sulphur dioxide, but some of these may have adverse side-effects. **Irradiation** is a method of food preservation in which the bacteria are killed by irradiating the food with gamma rays.

food production *See* AGRICULTURE.

food reserves Reserves of fat, carbohydrate, or (rarely) protein in cells and tissues that function as an important store of energy that can be released and used in ATP production when required by the organism. For example, in animals *fat is stored in adipose tissue, and carbohydrate – in the form of the **storage compound** *glycogen – is stored in liver and muscle cells. In plants *starch is a major storage compound, being found in perennating organs (*see* PERENNATION) and seeds (in which it is mobilized at germination), and oils are important storage materials in some species (e.g. in the seeds of the castor-oil plant).

food supply (in human ecology) The production of food for human consumption. *See* AGRICULTURE.

food web A system of *food chains that are linked with one another. In a food web a particular organism may feed at more than one trophic level. For example, in a pond food web a freshwater mussel may feed directly on green algae, in which case it is a primary consumer. However, it can also feed on protozoa, which are themselves primary

consumers, in which case the mussel is the secondary consumer. A food web does not usually include the decomposers, but these organisms are very important in the flow of energy through a food web (*see* ENERGY FLOW).

fool's gold *See* PYRITE.

foot The unit of length in *f.p.s. units. It is equal to one-third of a yard and is now therefore defined as 0.3048 metre. Several units based on the foot were formerly used in science, including the units of work, the **foot-pound-force** and the **foot-poundal**, and the illumination units, the **foot-candle** and the **foot-lambert**. These have all been replaced by SI units.

foramen An aperture in an animal part or organ, especially one in a bone or cartilage. For example, the **foramen magnum** is the opening at the base of the skull through which the *spinal cord passes.

forbidden band *See* ENERGY BANDS.

forbidden transitions Transitions between energy levels in a quantum-mechanical system that are not allowed to take place because of *selection rules. In practice, forbidden transitions can occur, but they do so with much lower probability than allowed transitions. There are three reasons why forbidden transitions may occur:
(1) the selection rule that is violated is only an approximate rule. An example is provided by those selection rules that are only exact in the absence of *spin–orbit coupling. When spin–orbit coupling is taken into account, the forbidden transitions become allowed – their strength increasing with the size of the spin–orbit coupling;
(2) the selection rule is valid for dipole radiation, i.e. in the interaction between a quantum-mechanical system, such as an atom, and an electromagnetic field, only the (variable) electric dipole moment is considered. Actual transitions may involve magnetic dipole radiation or quadrupole radiation;
(3) the selection rule only applies for an atom, molecule, etc., in isolation and does not necessarily apply if external fields, collisions, etc., are taken into account.

force Symbol *F*. The agency that tends to change the momentum of a massive body, defined as being proportional to the rate of increase of momentum. For a body of mass *m* travelling at a velocity *v*, the momentum is *mv*. In any coherent system of units the force is therefore given by $F = \mathrm{d}(mv)/\mathrm{d}t$. If the mass is constant $F = m\mathrm{d}v/\mathrm{d}t = ma$, where *a* is the acceleration (*see* NEWTON'S LAWS OF MOTION). The SI unit of force is the newton. Forces occur always in equal and opposite action–reaction pairs between bodies, though it is often convenient to think of one body being in a force *field.

forced convection *See* CONVECTION.

force ratio (mechanical advantage) The ratio of the output force (load) of a machine to the input force (effort).

forebrain (prosencephalon) One of the three sections of the brain of a vertebrate embryo. The forebrain develops to form the *cerebrum, *hypothalamus, and *thalamus in the adult. *Compare* HINDBRAIN; MIDBRAIN.

foregut **1.** The anterior region of the alimentary canal of vertebrates, up to the anterior part of the duodenum. **2.** The anterior part of the alimentary canal of arthropods. *See also* HINDGUT; MIDGUT.

forest An area of vegetation in which the dominant plants are trees; forests constitute major *biomes. Temperate forests have adequate or abundant rainfall and moderate temperatures. They may be dominated by deciduous trees (such as oak, ash, elm, beech, or maple), often growing together to form mixed deciduous forest, as in temperate regions of Europe, Asia, and North America; or by broad-leaved evergreens (such as southern beech, *Nothofagus*), as in Chile. Cold forests, of northern regions, are dominated by evergreen conifers (*see* TAIGA). Tropical forests include *rainforest; monsoon forest, found in SE Asia and having heavy rainfall interspersed with periods of drought; and thorn forest, as in SW North America, SW Africa, and parts of Central and South America and Australia, which has sparse rainfall, is dominated by small thorny trees, and grades into savanna woodland and semidesert. *See also* DEFORESTATION.

form **1.** A category used in the *classification of organisms into which different types of a variety may be placed. **2.** Any distinct variant within a species. Seasonal variants, e.g. the tawny brown (summer) and blue-white (winter) forms of the blue hare, may be called forms. *See also* POLYMORPHISM.

formaldehyde *See* METHANAL.

formalin A colourless solution of methanal (formaldehyde) in water with

methanol as a stabilizer; r.d. 1.075–1.085. When kept at temperatures below 25°C a white polymer of methanal separates out. It is used as a disinfectant and preservative for biological specimens.

formate *See* METHANOATE.

formic acid *See* METHANOIC ACID.

formula **1.** (in chemistry) A way of representing a chemical compound using symbols for the atoms present. Subscripts are used for the numbers of atoms. The **molecular formula** simply gives the types and numbers of atoms present. For example, the molecular formula of ethanoic acid is $C_2H_4O_2$. The **empirical formula** gives the atoms in their simplest ratio; for ethanoic acid it is CH_2O. The **structural formula** gives an indication of the way the atoms are arranged. Commonly, this is done by dividing the formula into groups; ethanoic acid can be written $CH_3.CO.OH$ (or more usually simply CH_3COOH). Structural formulae can also show the arrangement of atoms or groups in space. **2.** (in mathematics and physics) A rule or law expressed in algebraic symbols.

formula weight The relative molecular mass of a compound as calculated from its molecular formula.

formylation A chemical reaction that introduces a formyl group (methanoyl, –CHO) into an organic molecule.

formyl group The group HCO–.

Fortin barometer *See* BAROMETER.

forward genetics The traditional approach to genetic investigation, in which the aim is to identify the gene that governs a particular known function (identified by the effect of a mutation of that gene). *Compare* REVERSE GENETICS.

fossil The remains or traces of any organism that lived in the geological past. In general only the hard parts of organisms become fossilized (e.g. bones, teeth, shells, and wood) but under certain circumstances the entire organism is preserved. For example, virtually unaltered fossils of extinct mammals, such as the woolly mammoth and woolly rhinoceros, have been found preserved in ice in the Arctic. Small organisms or parts of organisms (e.g. insects, leaves, flowers) have been preserved in *amber.

In the majority of fossils the organism has been turned to stone – a process known as **petrification**. This may take one of three forms. In **permineralization**, solutions originating underground fill the microscopic cavities in the organism. Minerals in these solutions (e.g. silica or calcite) may actually replace the original material of the organism so that even microscopic structures may be preserved; this process is known as **replacement** (or **mineralization**). A third form of petrification – **carbonization** (or **distillation**) – occurs in certain soft tissues that are composed chiefly of compounds of carbon, hydrogen, and oxygen (e.g. cellulose). After the organism has been buried, and in the absence of oxygen, carbon dioxide and water are liberated until only free carbon remains. This forms a black carbon film in the rock outlining the original organism. **Moulds** are formed when the original fossil is dissolved away leaving a mould of its outline in the solid rock. The deposition of mineral matter from underground solutions in a mould forms a **cast**. Palaeontologists often produce casts from moulds using such substances as dental wax. Moulds of thin organisms (e.g. leaves) are commonly known as **imprints**. **Trace fossils** are the fossilized remnants of the evidence of animal life, such as tracks, trails, footprints, burrows, and **coprolites** (fossilized faeces).

The ideal conditions for the formation of fossils occur in areas of rapid sedimentation, especially those parts of the seabed that lie below the zone of wave disturbance. *See also* CHEMICAL FOSSIL; INDEX FOSSIL; MICROFOSSIL.

fossil fuel Coal, oil, and natural gas, the fuels used by humans as a source of energy. They are formed from the remains of living organisms and all have a high carbon or hydrogen content. Their value as fuels relies on the exothermic oxidation of carbon to form carbon dioxide ($C + O_2 \rightarrow CO_2$) and the oxidation of hydrogen to form water ($H_2 + \frac{1}{2}O_2 \rightarrow H_2O$). Fossil fuels are a major source of the greenhouse gas carbon dioxide; as such, their use contributes to the *greenhouse effect and global warming.

fossil hominid *See* HOMINID.

Foucault pendulum A simple pendulum in which a heavy bob attached to a long wire is free to swing in any direction. As a result of the earth's rotation, the plane of the pendulum's swing slowly turns (at the poles of the earth it makes one complete revolution in 24 hours). It was devised by the French physi-

cist Jean Bernard Léon Foucault (1819–68) in 1851, when it was used to demonstrate the earth's rotation.

Fourier analysis The representation of a function f(x), which is periodic in x, as an infinite series of sine and cosine functions,

$$f(x) = a_0/2 + \sum_{n=1}^{\infty} (a_n \cos nx + b_n \sin nx)$$

A series of this type is called a *Fourier series. If the function is periodic with a period 2π, the coefficients a_0, a_n, b_n are:

$$a_0 = \int_{-\pi}^{+\pi} f(x)\,dx,$$

$$a_n = \int_{-\pi}^{+\pi} f(x)\cos nx\,dx \ (n = 1,2,3,\ldots),$$

$$b_n = 1/\pi \int_{-\pi}^{+\pi} f(x)\sin nx\,dx \ (n = 1,2,3,\ldots).$$

Fourier analysis and Fourier series are named after the French mathematician and engineer Joseph Fourier (1768–1830). Fourier series have many important applications in mathematics, science, and engineering, having been invented by Fourier in the first quarter of the 19th century in his analysis of the problem of heat *conduction.

Fourier series An expansion of a periodic function as a series of trigonometric functions. Thus,

$$f(x) = a_0 + (a_1 \cos x + b_1 \sin x) + (a_2 \cos 2x + b_2 \sin 2x) + \ldots,$$

where a_0, a_1, b_1, b_2, etc., are constants, called **Fourier coefficients**. The series is used in *Fourier analysis.

Fourier transform An integral transform of the type:

$$F(y) = \int_{-\infty}^{\infty} f(x)e^{-xy}\,dy.$$

The inverse is:

$$f(x) = (1/2\pi) \int_{-\infty}^{\infty} F(y)e^{ixy}\,dy.$$

Fourier transform techniques are used in obtaining information from spectra, especially in NMR and infrared spectroscopy (*see* FOURIER-TRANSFORM INFRARED).

Fourier-transform infrared (FT-IR) Infrared spectroscopy in which computers are part of the spectroscopic apparatus and use *Fourier transforms to enable the curve of intensity against wave number to be plotted with very high sensitivity. This has allowed spectra to be obtained in the far infrared region; previously it was difficult to attain spectra in this region as the resolution was obscured by the signal-to-noise ratio being too high to resolve the vibrational and/or rotational spectra of small molecules in their gas phase. FT-IR has been used in research on the atmosphere. Another application of this technique is the detection of impurities in samples of condensed matter.

four-level laser A laser in which four energy levels are involved. The disadvantage of a three-level laser is that it is difficult to attain population inversion because many molecules have to be raised from their ground state to an excited state by pumping. In a four-level laser, the laser transition finishes in an initially unoccupied state F, having started in a state I, which is not the ground state. As the state F is initially unoccupied, any population in I constitutes population inversion. Thus laser action is possible if I is sufficiently metastable. If transitions from F to the ground state G are rapid, population inversion is maintained since this lowers the population in F caused by the transition in the laser action.

fourth dimension *See* SPACE–TIME.

four-wave mixing In nonlinear optics, the production of a photon in a medium as a result of the interaction of three photons. In four-wave mixing, the photon produced has a wavelength (frequency) that is different from the wavelength (frequencies) of any of the three original photons. The effect is important in optical fibres; it can lead to loss of signal when a number of wavelengths are transmitted along the same fibre.

fovea (fovea centralis) A shallow depression in the *retina of the eye, opposite the lens, that is present in some vertebrates. This area contains a large concentration of *cones with only a thin layer of overlying nerves. It is therefore specialized for the perception of colour and sharp intense images. The clarity is enhanced in animals with binocular vision.

f.p.s. units The British system of units based on the foot, pound, and second. It has now been replaced for all scientific purposes by SI units.

fractal A curve or surface generated by a process involving successive subdivision. For example, a **snowflake curve** can be produced by starting with an equilateral triangle and dividing each side into three segments. The middle segments are then replaced by two equal segments, which would form the sides of a smaller equilateral triangle. This gives a 12-sided star-shaped figure. The next stage is to subdivide each of the sides of this

figure in the same way, and so on. The result is a developing figure that resembles a snowflake. In the limit, this figure has 'fractional dimension' – i.e. a dimension between that of a line (1) and a surface (2); the dimension of the snowflake curve is 1.26. The study of this type of 'self-similar' figure is used in certain branches of physics – for example, crystal growth. Fractals are also important in *chaos theory and in computer graphics. *See also* MANDELBROT SET.

fraction *See* FRACTIONAL DISTILLATION.

fractional crystallization A method of separating a mixture of soluble solids by dissolving them in a suitable hot solvent and then lowering the temperature slowly. The least soluble component will crystallize out first, leaving the other components in solution. By controlling the temperature, it is sometimes possible to remove each component in turn.

fractional distillation (fractionation) The separation of a mixture of liquids by distillation. Effective separation can be achieved by using a long vertical column (**fractionating column**) attached to the distillation vessel and filled with glass beads. Vapour from the liquid rises up the column until it condenses and runs back into the vessel. The rising vapour in the column flows over the descending liquid, and eventually a steady state is reached in which there is a decreasing temperature gradient up the column. The vapour in the column has more volatile components towards the top and less volatile components at the bottom. Various **fractions** of the mixture can be drawn off at points on the column. Industrially, fractional distillation is performed in large towers containing many perforated trays. It is used extensively in petroleum refining.

fractionating column *See* FRACTIONAL DISTILLATION.

fractionation *See* FRACTIONAL DISTILLATION.

fragmentation A method of asexual reproduction, occurring in some invertebrates, in which parts of the organism break off and subsequently differentiate and develop into new individuals. It occurs especially in certain cnidarians and annelids. Regeneration may occur before separation, producing chains of individuals budding from the parent.

frame dragging *See* LENSE–THIRRING EFFECT.

frame of reference A set of axes, taken as being for practical purposes at rest, that enables the position of a point (or body) in space to be defined at any instant of time. In a four-dimensional continuum (*see* SPACE–TIME) a frame of reference consists of a set of four coordinate axes, three spatial and one of time.

francium Symbol Fr. A radioactive element belonging to group 1 of the periodic table; a.n. 87; r.d. 2.4; m.p. 27±1°C; b.p. 677±1°C. The element is found in uranium and thorium ores. All 22 known isotopes are radioactive, the most stable being francium–223. The existence of francium was confirmed by Marguerite Perey in 1939.

SEE WEB LINKS

- Information from the WebElements site

Frank, Ilya *See* CERENKOV, PAVEL ALEKSEYEVICH.

Frank–Kasper phase A phase that occurs in certain complex alloys involving both icosahedra and tetrahedra packed closely together. *See also* QUASICRYSTAL.

Franklin, Benjamin (1706–90) American scientist and statesman who held various government posts. As an amateur scientist he experimented with electricity, introducing the concepts of 'positive' and 'negative'. In 1752 he carried out the extremely dangerous experiment of flying a kite during a thunderstorm and proved the electrical nature of lightning. He also invented the lightning conductor.

Franklin, Rosalind *See* CRICK, FRANCIS HARRY COMPTON.

Frasch process A method of obtaining sulphur from underground deposits using a tube consisting of three concentric pipes. Superheated steam is passed down the outer pipe to melt the sulphur, which is forced up through the middle pipe by compressed air fed through the inner tube. The steam in the outer casing keeps the sulphur molten in the pipe. It was named after the German-born US chemist Hermann Frasch (1851–1914).

fraternal twins (dizygotic twins) Two individuals that result from a single pregnancy, each having developed from a separate fertilized egg. The two egg cells contain different combinations of *alleles as do the

sperm that fertilize them. The twins therefore have no more genetic similarity than brothers or sisters from single births. *Compare* IDENTICAL TWINS.

Fraunhofer, Josef von (1787–1826) German physicist, who trained as an optician. In 1814 he observed dark lines in the spectrum of the sun (*see* FRAUNHOFER LINES). He also studied *Fraunhofer diffraction.

Fraunhofer diffraction A form of *diffraction in which the light source and the receiving screen are in effect at infinite distances from the diffracting object, so that the wave fronts can be treated as planar rather than spherical. In practice it involves parallel beams of light. It can be regarded as an extreme case of *Fresnel diffraction but is of more practical use in explaining single and multiple slit patterns.

Fraunhofer lines Dark lines in the solar spectrum that result from the absorption by elements in the solar chromosphere of some of the wavelengths of the visible radiation emitted by the hot interior of the sun.

free electron *See* ELECTRON.

free-electron laser A type of *laser that works by the stimulated emission of electromagnetic radiation produced by the motion of electrons moving rapidly in external magnetic fields. A beam of electrons at relativistic speed is produced in an accelerator and passed into a region in which the electrons are forced to follow a sinusoidal path by an array of magnets (the 'undulator'). The associated *synchrotron radiation is highly coherent as in a conventional laser. Free-electron lasers can be tuned to a narrow frequency range and radiation can be produced over a wide range, from microwaves to soft X-rays. The free-electron-laser mechanism might account for some aspects of pulsar radiation.

free energy A measure of a system's ability to do work. The **Gibbs free energy** (or **Gibbs function**), G, is defined by $G = H - TS$, where G is the energy liberated or absorbed in a reversible process at constant pressure and constant temperature (T), H is the *enthalpy and S the *entropy of the system. Changes in Gibbs free energy, ΔG, are useful in indicating the conditions under which a chemical reaction will occur. If ΔG is positive the reaction will only occur if energy is supplied to force it away from the equilibrium position (i.e. when $\Delta G = 0$). If ΔG is negative the reaction will proceed spontaneously to equilibrium.

The **Helmholtz free energy** (or **Helmholtz function**), F, is defined by $F = U - TS$, where U is the *internal energy. For a reversible isothermal process, ΔF represents the useful work available.

free fall Motion resulting from a gravitational field that is unimpeded by a medium that would provide a frictional retarding force or buoyancy. In the earth's gravitational field, free fall takes place at a constant acceleration, known as the *acceleration of free fall.

free radical An atom or group of atoms with an unpaired valence electron. Free radicals can be produced by photolysis or pyrolysis in which a bond is broken without forming ions (*see* HOMOLYTIC FISSION). Because of their unpaired valence electron, most free radicals are extremely reactive. *See also* CHAIN REACTION.

free space A region in which there is no matter and no electromagnetic or gravitational fields. It has a temperature of absolute zero, unit refractive index, and the speed of light is its maximum value. The electric constant (*see* PERMITTIVITY) and the magnetic constant (*see* PERMEABILITY) are defined for free space.

freeze drying A process used in dehydrating food, blood plasma, and other heat-sensitive substances. The product is deep-frozen and the ice trapped in it is removed by reducing the pressure and causing it to sublime. The water vapour is then removed, leaving an undamaged dry product.

freeze fracture A method of preparing material for electron microscopy that allows the visualization of the interior of plasma membranes and organelles. Cells are frozen at –196°C and cracked so that the plane of fracture runs through the middle of *lipid bilayers, separating the two halves. The exposed surfaces are then coated with carbon and platinum and the organic material is digested with enzymes (**freeze etching**), leaving a carbon–platinum replica of the fractured surface, which can be examined using the microscope.

freezing mixture A mixture of components that produces a low temperature. For example, a mixture of ice and sodium chloride gives a temperature of –20°C.

freezing-point depression *See* DEPRESSION OF FREEZING POINT.

Frenkel defect *See* CRYSTAL DEFECT (Feature).

freon *See* CHLOROFLUOROCARBON.

frequency Symbol f or ν. The rate of repetition of a regular event. The number of cycles of a wave, or some other oscillation or vibration, per second is expressed in *hertz. The frequency (f) of a wave motion is given by $f = c/\lambda$, where c is the velocity of propagation and λ is the wavelength. The frequency associated with a quantum of electromagnetic energy is given by $f = E/h$, where E is the quantum's energy and h is the Planck constant.

frequency modulation (FM) *See* MODULATION; RADIO.

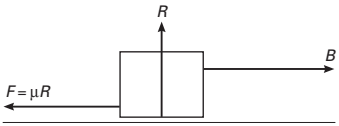
fresnel A unit of frequency equal to 10^{12} hertz. In SI units this is equal to 1 terahertz (THz). It was named after the French physicist A. J. Fresnel (1788–1827).

Fresnel diffraction A form of *diffraction in which the light source or the receiving screen, or both, are at finite distances from the diffracting object, so that the wavefronts are not plane, as in *Fraunhofer diffraction. It was studied by A. J. Fresnel.

Fresnel lens A lens with one face cut into a series of steps. It enables a relatively light and robust lens of short focal length though poor optical quality to be used in projectors (as condenser lenses), searchlights, spotlights, car headlights, and lighthouses. Such lenses have been made fine enough to serve as magnifiers for reading small print.

friction The force that resists the motion of one surface relative to another with which it is in contact. For a body resting on a horizontal surface there is a normal contact force, R, between the body and surface, acting perpendicularly to the surface. If a horizontal force B is applied to the body with the intention of moving it to the right, there will be an equal horizontal friction force, F, to the left, resisting the motion (see illustration). If B is increased until the body just moves, the value of F will also increase until it reaches the **limiting frictional force** (F_L), which is the maximum value of F. F_L is then equal to $\mu_s R$, where μ_s is the **coefficient of static friction**, the value of which depends on the nature of the surfaces. Once the body is moving with constant velocity, the value of F falls to a value F_k, which is equal to $\mu_k R$, where μ_k is the **coefficient of kinetic friction**. Both μ_s and μ_k are independent of the surface area of the body unless this is very small and μ_k is almost independent of the relative velocity of the body and surface.

Friction occurs because surfaces, however smooth they may look to the eye, have many microscopic humps and crests. Therefore the actual area of contact is very small, and the consequent very high pressure leads to local pressure welding of the surfaces. During motion the welds are broken and remade continually. *See also* ROLLING FRICTION.



Friction.

Friedel–Crafts reaction A type of reaction in which an alkyl group (from a haloalkane) or an acyl group (from an acyl halide) is substituted on a benzene ring (see illustration overleaf). The product is an alkylbenzene (for alkyl substitution) or an alkyl aryl ketone (for acyl substitution). The reactions occur at high temperature (about 100°C) with an aluminium chloride catalyst. The catalyst acts as an electron acceptor for a lone pair on the halide atom. This polarizes the haloalkane or acyl halide, producing a positive charge on the alkyl or acyl group. The mechanism is then electrophilic substitution. Alcohols and alkenes can also undergo Friedel–Crafts reactions. The reaction is named after the French chemist Charles Friedel (1832–99) and the US chemist James M. Crafts (1839–1917).

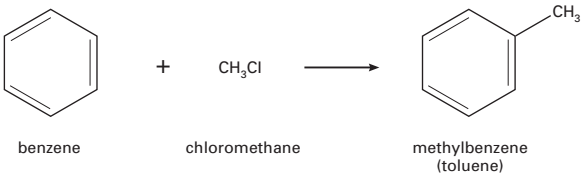
Frisch, Karl von *See* LORENZ, KONRAD ZACHARIAS.

Froehde's test A *presumptive test for opioids. **Froehde's reagent** consists of 0.5 gram of sodium molybdate (Na_2MoO_4) dissolved in 100 ml of concentrated sulphuric acid. Opioids give a pink to purple colour.

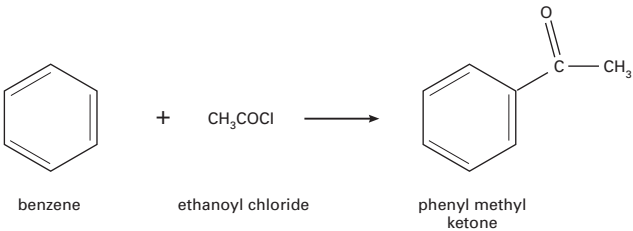
frogs *See* AMPHIBIA.

frond *See* MEGAPHYLL.

front (in meteorology) The sloping interface between two *air masses of different origins and thermal characteristics (e.g. temperature and humidity). Where the air



Friedel–Crafts methylation



Friedel–Crafts acetylation

Friedel-Crafts reaction.

masses come together the warm air, being lighter, rises and slopes over the colder air. Distinctive weather phenomena are associated with fronts. At a **warm front** (the boundary zone at the front of the warm sector of a *depression), warm air is overtaking cold air and rising above it with a slope of about 1:150. This is associated with cirrus clouds followed by cirrostratus, altostratus, then nimbostratus clouds, as the warm front passes. At a **cold front**, which is usually found to the rear of a depression, warm air is forced to rise by an advancing undercutting wedge of cold air. This is accompanied by a sudden veering of the wind, a fall in temperature, and heavy rainfall. An **occluded front** (or **occlusion**) occurs when a cold front overtakes a warm front in an atmospheric depression.

frontal lobe The anterior part of each cerebral hemisphere, which is associated with the higher mental functions, such as abstract thought.

frontier-orbital theory A theory of the reactions of molecules that emphasizes the energies and symmetries of **frontier orbitals**: the two orbitals in a molecule that are the occupied orbital of highest energy and the unoccupied orbital of lowest energy. Frontier orbital theory was developed by the Japanese chemist Kenichi Fukui (1919–98) in the 1950s and is an alternative approach to the *Woodward–Hoffmann rules. It has been very successful in explaining such reactions as the *Diels–Alder reaction.

Frost diagram A graph showing how standard electrode potentials vary with oxidation state for different oxidation states of an element. Frost diagrams can be constructed from *Latimer diagrams. For an element M, the standard electrode potential $E^{\ominus}$ is calculated for the reaction.

$$M(N) + Ne^- \rightarrow M(0)$$

where M(N) indicates the species in oxidation state N and M(0) indicates the zero oxidation state. The Frost diagram is then obtained by plotting $NE^{\ominus}$ against N for the different species. $NE^{\ominus}$ is proportional to the standard Gibbs free energy of the particular half reaction.

In a Frost diagram, the lowest point corresponds to the most stable oxidation state of the element. Also, the slope of a line between two points is the standard potential of the couple represented by the points. Like Latimer diagrams, Frost diagrams depend on pH.

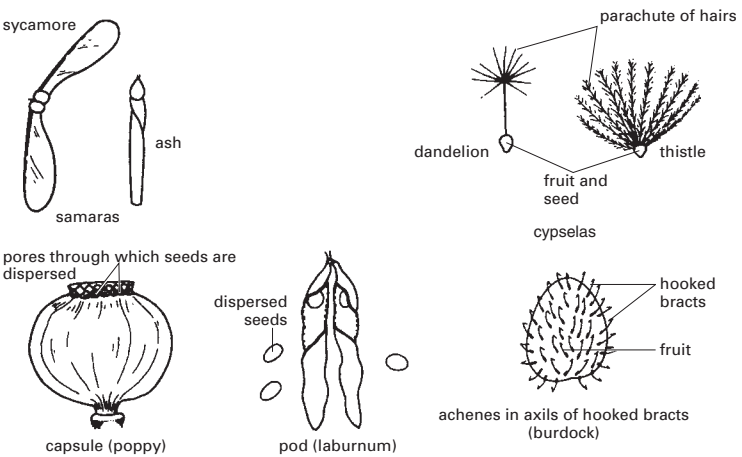
froth flotation A method of separating mixtures of solids, used industrially for sepa-

rating ores from the unwanted gangue. The mixture is ground to a powder and water and a frothing agent added. Air is blown through the water. With a suitable frothing agent, the bubbles adhere only to particles of ore and carry them to the surface, leaving the gangue particles at the bottom.

fructification *See* SPOROPHORE.

fructose (fruit sugar; laevulose) A simple sugar, $C_6H_{12}O_6$, stereoisomeric with glucose (*see* MONOSACCHARIDE). (Although natural fructose is the D-form, it is in fact laevorotatory.) Fructose occurs in green plants, fruits, and honey and tastes sweeter than sucrose (cane sugar), of which it is a constituent. Derivatives of fructose are important in the energy metabolism of living organisms. Fructose derived from corn starch is now used extensively in food manufacturing as a sucrose substitute.

fruit The structure formed from the ovary of a flower, usually after the ovules have been fertilized. It consists of the **fruit wall** (*see* PERICARP) enclosing the seed(s). Other parts of the flower, such as the receptacle, may develop and contribute to the structure, resulting in a **false fruit** (*see* PSEUDOCARP). The fruit may retain the seeds and be dispersed whole (an **indehiscent fruit**), or it may open (dehisce) to release the seeds (a **dehiscent fruit**). Fruits are divided into two main groups depending on whether the



Fruit.

ovary wall remains dry or becomes fleshy (**succulent**). Succulent fruits are generally dispersed by animals and dry fruits by wind, water, or by some mechanical means. See illustration. *See also* COMPOSITE FRUIT.

fruit fly *See* DROSOPHILA.

fruit sugar *See* FRUCTOSE.

frustration A situation in which there are competing interactions in a system. For example, in a *spin glass the magnetic atoms are subject to both ferromagnetic and antiferromagnetic interactions. Frustration also occurs in the folding of large polymer molecules due to parts of the molecule getting in each other's way. It is thought that proteins fold readily to specific shapes because they have evolved to minimize this type of steric frustration.

frustum A solid figure produced when two parallel planes cut a larger solid or when one plane parallel to the base cuts it.

FSH *See* FOLLICLE-STIMULATING HORMONE.

FTP (file transfer protocol) The protocol used on the *Internet for transferring files (downloading or uploading) from one computer to another.

5-FU *See* 5-FLUOROURACIL.

fucoxanthin The major *carotenoid pigment present, with chlorophyll, in the brown algae (*see* PHAEOPHYTA).

fuel A substance that is oxidized or otherwise changed in a furnace or heat engine to release useful heat or energy. For this purpose wood, vegetable oil, and animal products have largely been replaced by *fossil fuels since the 18th century.

The limited supply of fossil fuels has encouraged the development of *renewable energy sources.

fuel cell A cell in which the chemical energy of a fuel is converted directly into electrical energy. The simplest fuel cell is one in which hydrogen is oxidized to form water over porous sintered nickel electrodes. A supply of gaseous hydrogen is fed to a compartment containing the porous anode and a supply of oxygen is fed to a compartment containing the porous cathode; the electrodes are separated by a third compartment containing a hot alkaline electrolyte, such as potassium hydroxide. The electrodes are porous to enable the gases to react with the electrolyte, with the nickel in the electrodes acting as a catalyst. At the anode the hydrogen reacts with the hydroxide ions in the electrolyte to form water, with the release of two electrons per hydrogen molecule:

$$H_2 + 2OH^- \rightarrow 2H_2O + 2e^-$$

At the cathode, the oxygen reacts with the water, taking up electrons, to form hydroxide ions:

$$\tfrac{1}{2}O_2 + H_2O + 2e^- \rightarrow 2OH^-$$

The electrons flow through an external circuit as an electric current. The device is a more efficient converter of electric energy than a heat engine, but it is bulky and requires a continuous supply of gaseous fuels. Their use to power electric vehicles is being actively explored. The second generation of fuel cells uses molten salts, particularly lithium or potassium carbonate, as electrolytes. The third generation uses solid conducting ionic oxides. *See also* BIOCHEMICAL FUEL CELL.

fuel element *See* NUCLEAR REACTOR.

fugacity Symbol *f*. A thermodynamic function used in place of partial pressure in reactions involving real gases and mixtures. For a component of a mixture, $d(\ln f) = d\mu / RT$, where μ is the chemical potential. It has the same units as pressure and the fugacity of a gas is equal to the pressure if the gas is ideal. The fugacity of a liquid or solid is the fugacity of the vapour with which it is in equilibrium. The ratio of the fugacity to the fugacity in some standard state is the *activity. For a gas, the standard state is chosen to be the state at which the fugacity is 1. The activity then equals the fugacity.

fullerene *See* BUCKMINSTERFULLERENE.

fullerite *See* BUCKMINSTERFULLERENE.

fuller's earth A naturally occurring clay material (chiefly montmorillonite) that decolorizes oil and grease. In the past raw wool was cleaned and whitened by kneading it in water with fuller's earth; a process known as **fulling**. Fuller's earth is now widely used to decolorize fats and oils and also as an insecticide carrier and drilling mud. The largest deposits occur in the USA, UK, and Japan.

full-wave rectifier *See* RECTIFIER.

fulminate *See* CYANIC ACID.

fulminic acid *See* CYANIC ACID.

fumaric acid *See* BUTENEDIOIC ACID.

function Any operation or procedure that

relates one variable to one or more other variables. If y is a function of x, written $y = f(x)$, a change in x produces a change in y, and if x is known, y can be determined. x is the **independent variable** and y is the **dependent variable**.

functional A function of a function. Functionals are used very extensively in the quantum-mechanical many-body problem, statistical mechanics, and quantum field theory.

functional group The group of atoms responsible for the characteristic reactions of a compound. The functional group is –OH for alcohols, –CHO for aldehydes, –COOH for carboxylic acids, etc.

fundamental *See* HARMONIC.

fundamental constants (universal constants) Those parameters that do not change throughout the universe. The charge on an electron, the speed of light in free space, the Planck constant, the gravitational constant, the electric constant, and the magnetic constant are all thought to be examples. It has been suggested that some fundamental constants might change with time, although there is no conclusive evidence that this occurs.

SEE WEB LINKS

- Values of fundamental physical constants from NIST

fundamental interactions The four different types of interaction that can occur between bodies. These interactions can take place even when the bodies are not in physical contact and together they account for all the observed forces that occur in the universe. While the unification of these four types of interaction into a single theory has long been the aim of physicists, this has not yet been fully achieved. *See also* ELEMENTARY PARTICLES; GAUGE THEORY; UNIFIED-FIELD THEORY.

The **gravitational interaction**, some 10^{40} times weaker than the electromagnetic interaction, is the weakest of all. The force that it generates acts between all bodies that have mass and the force is always attractive. The interaction can be visualized in terms of a classical *field of force in which the strength of the force falls off with the square of the distance between the interacting bodies (*see* NEWTON'S LAW OF GRAVITATION). The hypothetical gravitational quantum, the **graviton**, is also a useful concept in some contexts. On the atomic scale the gravitational force is negligibly weak, but on the cosmological scale, where masses are enormous, it is immensely important in holding the components of the universe together. Because gravitational interactions are long-ranged, there is a well-defined macroscopic theory in general relativity. At present, there is no satisfactory quantum theory of gravitational interaction.

The **weak interaction**, some 10^{10} times weaker than the electromagnetic interaction, occurs between *leptons and in the decay of hadrons. It is responsible for the *beta decay of particles and nuclei. In the current model, the weak interaction is visualized as a force mediated by the exchange of virtual particles, called intermediate vector bosons. The weak interactions are described by *electroweak theory, which unifies them with the electromagnetic interactions.

The **electromagnetic interaction** is responsible for the forces that control atomic structure, chemical reactions, and all electromagnetic phenomena. It accounts for the forces between charged particles, but unlike the gravitational interaction, can be either attractive or repulsive. Some neutral particles decay by electromagnetic interaction. The interaction is either visualized as a classical field of force (*see* COULOMB'S LAW) or as an exchange of virtual *photons. As with gravitational interactions, the fact that electromagnetic interactions are long-ranged means that they have a well-defined classical theory given by *Maxwell's equations. The quantum theory of electromagnetic interactions is described by *quantum electrodynamics.

The **strong interaction**, some 10^2 times stronger than the electromagnetic interaction, functions only between *hadrons and is responsible for the force between nucleons that gives the atomic nucleus its great stability. It operates at very short range inside the nucleus (10^{-15} metre) and is visualized as an exchange of virtual mesons. The strong interactions are described by *quantum chromodynamics.

fundamental units A set of independently defined *units of measurement that forms the basis of a system of units. Such a set requires three mechanical units (usually of length, mass, and time) and, in some systems, one electrical unit; it has also been found convenient to treat certain other quantities as fundamental, even though they

are not strictly independent. In the metric system the centimetre–gram–second (c.g.s.) system was replaced by the metre–kilogram–second (m.k.s.) system; the latter now forms the basis for *SI units. In British Imperial units the foot–pound–second (f.p.s.) system was formerly used.

fungi A group of organisms formerly classified in the kingdom Fungi. Molecular studies have shown that fungi are more closely related to animals than plants, and fungi and animals are now classified in the assemblage opisthokonts. Fungi can either exist as single cells or make up a multicellular body called a *mycelium, which consists of filaments known as *hyphae. Most fungal cells are multinucleate and have cell walls composed chiefly of *chitin. Fungi exist primarily in damp situations on land and, because of the absence of chlorophyll, are either parasites or saprotrophs on other organisms. The principal criteria used in classification are the nature of the spores produced and the presence or absence of cross walls within the hyphae (*see* ASCOMYCOTA; BASIDIOMYCOTA; ZYGOMYCOTA). *See also* LICHENS.

SEE WEB LINKS

- Tree of Life survey of fungi, including phylogeny plus many links to other sites

fungicide *See* PESTICIDE.

Fungi Imperfecti *See* DEUTEROMYCOTA.

funicle The stalk that attaches an ovule to the placenta in the ovary of a flowering plant. It contains a strand of conducting tissue leading from the placenta into the chalaza.

furan A colourless liquid compound, C_4H_4O; r.d. 0.94; m.p. –86°C; b.p. 31.4°C. It has a five-membered ring consisting of four CH_2 groups and one oxygen atom.

furanose A *sugar having a five-membered ring containing four carbon atoms and one oxygen atom.

furfural A colourless liquid, $C_5H_4O_2$, b.p. 162°C, which darkens on standing in air. It is the aldehyde derivative of *furan and occurs in various essential oils and in *fusel oil. It is used as a solvent for extracting mineral oils and natural resins and itself forms resins with some aromatic compounds.

fuse A length of thin wire made of tinned copper or a metal alloy of low melting point that is designed to melt at a specified current loading in order to protect an electrical device or circuit from overloading. The wire is often enclosed in a small glass or ceramic cartridge with metal ends.

fused ring *See* RING.

fusel oil A mixture of high-molecular weight *alcohols containing also esters and fatty acids, sometimes formed as a toxic impurity in the distillation products of alcoholic fermentation. It is used as a source of higher alcohols and in making paints and plastics.

fusible alloys Alloys that melt at low temperature (around 100°C). They have a number of uses, including constant-temperature baths, pipe bending, and automatic sprinklers to prevent fires from spreading. Fusible alloys are usually *eutectic mixtures of bismuth, lead, tin, and cadmium. Wood's metal and Lipowitz's alloy are examples of alloys that melt at about 70°C.

fusion **1.** Melting. **2.** *See* NUCLEAR FUSION. **3.** The combining together of cells, nuclei, or cytoplasm. *See* CELL FUSION; FERTILIZATION.

fusion reactor *See* THERMONUCLEAR REACTOR.

fuzzy logic A form of logic that allows for degrees of imprecision, used in *artificial intelligence studies. More traditional logics deal with two truth values: 'true' and 'false'. Fuzzy logics are multivalued dealing with concepts such as 'fairly true' and 'more or less true'. These can be represented by numbers within a range [0,1], with the number representing the degree of truth. **Fuzzy control** applies fuzzy logic to the computer-control of processes.